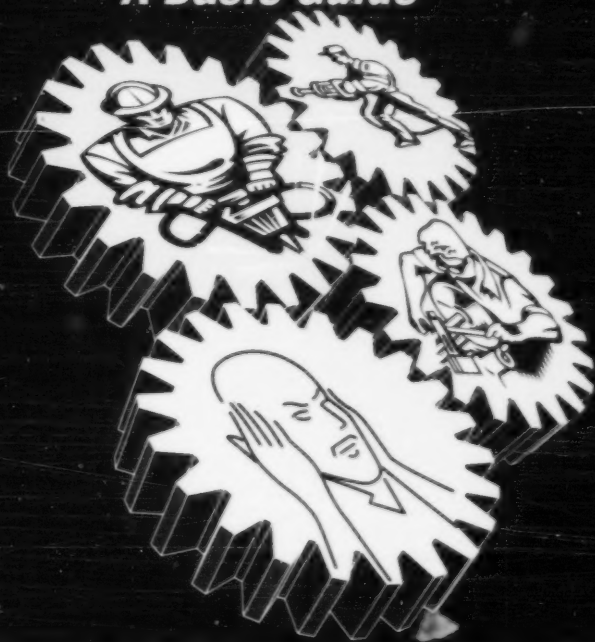


Noise Control in Industry:

A Basic Guide



Prepared by the Canadian Centre for Occupational Health and Safety

Emergency Information

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Fire

Police

Poison Control Centre

Doctor

Company Emergency Phone Number



Canadian Centre for Occupational Health and Safety

135 Hunter Street East, Hamilton Ontario Canada L8N 1M5

Noise Control In Industry:

A Basic Guide



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Objectives

This guide will enable you to:

- develop an understanding of recognition methods and control methods for occupational noise exposure;
- identify jobs that can potentially pose a risk of harmful noise exposure;
- plan workplace noise surveys and personal noise exposure measurements;
- understand noise survey data and identify needs for further action; and
- develop and implement a hearing conservation program.

Scope

This guide provides basic knowledge and skills for preventing hearing loss due to noise exposure. It presents a step by step approach for dealing with workplace noise problems, namely:

- recognize potential noise problems;
- measure workplace noise levels and personal noise exposure levels (noise dose);
- evaluate the risk of hearing loss;
- develop and implement noise controls; and
- evaluate the effectiveness of controls.

This guide is written in plain, non-technical language. Details of mathematical techniques for calculations using decibel and other logarithmic quantities are beyond the scope of this guide. Such information is available from the Inquiries Service of the Canadian Centre for Occupational Health and Safety (CCOHS). For a detailed technical evaluation of noise exposure and implementation of control measures, a noise specialist should be consulted.

Target Audience

This guide is for workers, their supervisors, health and safety committee members, health and safety representatives, industrial hygienists, occupational health and safety nurses and others with an interest in hearing conservation. The technical level of this guide meets the needs of the target audience.

Summary

Noise is a major occupational hazard. Short term effects of noise exposure include temporary hearing loss, stress, annoyance, difficulty in verbal communication, and safety hazards. The primary long-term health effect of noise exposure is permanent hearing loss. Both short-term and long-term effects can be prevented by timely recognition, evaluation and control of noise exposure.

This guide provides an overview of the methods of recognition, evaluation and control of workplace noise exposure. Topics covered include: a review of the units and measures of noise; methods of measuring noise level and noise exposure; instruments used to measure noise; the relationship between noise exposure and risk of hearing loss; noise exposure limits; engineering methods of noise control; and the effectiveness of hearing protectors. Basic components of a hearing conservation program are outlined.

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Introduction

Noise is a common occupational hazard. Noise exposure causes both immediate and long-term effects. The major long-term effect of noise exposure is permanent hearing loss. Noise-induced permanent hearing loss cannot be cured by medical treatment. Instead, it worsens as noise exposure continues and as the affected person ages.

In many cases hearing loss does not prevent people from performing their job. However, the social cost of hearing loss is extremely severe in terms of frustration, isolation and inability to participate in recreational activities.

The adverse health effects of noise exposure can be prevented, or at least minimized, by reducing noise exposure to safe levels. The best method of noise reduction is to implement engineering controls such as modifications to the noise source and/or to the workplace environment. Where technology cannot adequately control the problem, personal hearing protection such as ear muffs or plugs are used. The use of personal protection is only an interim measure while engineering controls for permanently reducing noise levels are being explored and implemented.

This guide will explain:

- basic facts on the units and measures of noise,
- how to measure workplace noise
- the instruments used to measure noise
- the health effects of noise exposure
- the relationship between noise exposure and hearing loss
- noise exposure limits
- engineering methods of controlling noise levels
- types and use of hearing protection

Details of mathematical techniques for calculations using decibel and other logarithmic quantities are beyond the scope of this guide. Such information is available in noise textbooks and also from the Inquiries Service of the Canadian Centre for Occupational Health and Safety (CCOHS).

Section I

Why Do We Worry About Noise

1. Health effects

Auditory Effects

2. Health Effects: Non-Auditory Effects

Physiological Effects

Performance Effects

3. Effect on Pregnancy

Why Do We Worry About Noise?

Noise is one of the major occupational hazards. Working in very noisy environments can adversely affect health and also cause safety concerns.

1. Health Effects: Auditory Effects

There are two kinds of health effects of noise:

1. Auditory effects
2. Non-auditory effects

Auditory effects are adverse effects of noise on the hearing ability of an exposed person. These effects include:

- Acoustic trauma
- Temporary hearing loss
- Tinnitus or ringing in the ear
- Permanent hearing loss

Permanent hearing loss has been the main concern related to occupational noise exposure.

Acoustic trauma is the sudden loss of hearing caused by a short burst of extremely loud noise, such as a gun shot.

Temporary hearing loss, also known as temporary threshold shift (TTS) occurs immediately after exposure to loud noise for several hours. Loss of hearing sensitivity is at a maximum immediately after noise exposure. Gradual recovery occurs when the affected person spends time in a quiet place. Complete recovery may take several hours.

Tinnitus is a buzzing or ringing noise in the ear. The condition may be temporary or last for several years.

Permanent hearing loss, also known as permanent threshold shift (PTS) progresses constantly as noise exposure continues month after month and year-after-year. The hearing impairment is usually not noticeable until it is substantial enough to interfere with routine

activities. At this stage, permanent and irreversible hearing damage has occurred which cannot be cured by medical treatment and will worsen as noise exposure continues.

When noise exposure ceases, noise induced hearing loss will not worsen but hearing sensitivity is not regained. In old age, hearing may worsen as age related-hearing loss adds to the noise-induced hearing loss.

2. Health Effects: Non-Auditory Effects

Non-auditory effects are the health effects of noise other than those related to hearing loss. Such effects can be divided into two categories: physiological effects and performance effects.

Physiological Effects

Examples of physiological effects are:

- The startling response to loud noise: muscles burst into activity, generally, with the intention to protect.
- The muscle tension response: where muscles tend to contract in the presence of loud noise.
- The respiratory reflexes: the respiratory rhythm tends to change when noise is present.
- Changes in the heartbeat pattern.
- Changes in the diameter of the blood vessels, particularly in the skin.

All these effects are similar to the response of the body to other causes of stress.

Performance Effects

Noise interferes with speech communication. This includes face-to-face talking, telephone conversation, and speech over a public address system.

In order to be understandable, the sound level of speech must be greater than the background noise at the ear of the listener. People with otherwise unnoticeable hearing loss find it difficult to understand spoken words in noisy surroundings.

Annoyance

Noise is annoying if the exposed individual(s) would like to reduce the noise, avoid, or leave the noisy area. The same noise could be annoying to some people but acceptable to others. There is no definite relationship between the degree of annoyance or unpleasantness of a noise and the risk of adverse health effects. For example, very loud music may be pleasant to one group of people and annoying to another, however both groups will be equally at risk of hearing loss.



FIGURE 1. Noise causes annoyance and stress

Job Interference

Depending on the type of activity, noise can severely affect the efficiency of task performance.

The following examples will illustrate this point:

- A nearby conversation can be distracting and reduce efficiency for mental tasks.
- A noisy environment can create an additional hazard, since alarms may not be heard.
- A noisy environment can interfere with verbal communication.

3. Effect on Pregnancy

The present state of knowledge does not state with certainty if a high level of noise is a danger to pregnancy. However, noise is a known stressor and stress can affect almost any bodily function, including pregnancy.

A study done at the Université de Montreal, Canada, indicated that excessive noise exposures during pregnancy may cause some hearing damage in the newborn. Chances of such damage are increased if the noise has a strong low-frequency component.

Studies on the relationship between fetal exposure to noise and the birth weight of babies have been inconclusive.

The U.S. Committee on Hearing, Bioacoustics and Biomechanics reviewed the scientific data on the effects on the embryo or fetuses of pregnant women who were exposed to high-intensity noise. The available data were found to be inconclusive to establish a definite link between noise exposure and adverse effects on pregnancy. As a result exposure limits could not be specified.

Sources of information on the effects of noise during pregnancy

Guidelines on pregnancy and work. Rockville, Md. : National Institute for Occupational Safety and Health, 1977.

Effect of noise on the fetus. JOM : Journal of Occupational Medicine. Vol. 29, no. 10 (Oct. 1987) p. 791.

Prenatal effects of exposure to high-level noise: report of Working Group 85 US: National Academy Press, 1982

Schell, L.M. *Environmental noise and human prenatal growth.* American Journal of Physical Anthropology. Vol. 56 (1981) p. 63-70

Lelande, N.M. et al. *Is occupational noise exposure during pregnancy a risk factor of damage to the auditory system of the fetus?* American Journal of Industrial Medicine. Vol. 10, no. 4 (1986). P. 427-435

Coblentz, A. et al. *Effects of fetal exposition to aircraft noise on the birth weight of children.* Proceedings of the Human Factors Society - 34th Annual Meeting, Orlando, Florida, October 8-12 (1990). P. 562-566

Ando, Y. et al. *Effects of intense noise during fetal life upon post-natal adaptability: statistical study of the reaction of babies to aircraft noise.* Journal of the Acoustical Society of America. Vol. 47, no. 2 (1970). P. 1128-1130

Basics of Noise

1. What is Noise?

2. How Do I Know If I Have a Noise Problem In My Workplace?

3. Production and Transmission of Noise

4. Units and Measures of Noise

Frequency

Sound Pressure

5. Units and Measures of Workplace Noise

A-Weighted Noise Levels

Sound Pressure Level and Sound Energy

Continuous, Variable, Intermittent and Impulse Noise

6. Sound Power

Relationship Between Sound Pressure

Level and Sound Power Level

Basics of Noise

1. What is Noise?

Sound is what we can hear. Noise is sound. A commonly used definition of noise is: unwanted sound. Other definitions include harmful sound, the undesirable byproduct of a process, sound that interferes with the hearing of meaningful sounds. In this guide, "sound" and "noise" are used interchangeably.

From the health and safety point of view, noise is sound with the potential for causing adverse health effects. This may include very loud desirable sounds as well. For example, very loud music has the potential to cause hearing loss and interfere with mainstream activities such as speech communication, the ability to hear warning sounds or concentrating on mental work.

2. How Do I Know If I Have a Noise Problem in My Workplace ?

The indicators of potentially hazardous noise level, include:

- noise is louder than busy city traffic;
- employees have to raise their voice to talk to someone about one metre (3 feet) away;
- at the end of their shift employees have to increase the volume of their radio or TV to a level too loud for others;
- after working for a few years in that workplace, employees find it difficult to communicate at a gathering or party situation where there are other sounds or many voices; and
- people hear a "ringing in the ear" after working in that workplace for a few years.

3. Production and Transmission of Noise

Noise (or sound) comes from vibrating objects. Vibration can result from air flow, high speed rotating machines, friction or mechanical impacts involved in machine operation. From the source, noise spreads out as a series of air pressure fluctuations known as sound waves. The spread of sound waves from the source to other locations occurs via the surrounding air or other media such as water and solids. This process of sound transmission or propagation is similar to the spread of ripples on the surface of a lake when a rock is dropped into in the water.

The following example (Figure 2) illustrates the production and transmission of sound waves. Imagine striking a drum surface with a stick. As a result of the impact, the drum surface vibrates back and forth. As it moves forward, it pushes the air in contact with the surface and produces a dense (high pressure) region in contact with the drum. When the surface moves in the opposite direction, it creates a rarified (low-pressure) region by decompressing the air in contact with the drum. As the drum surface vibrates, it creates alternating regions of high and low pressure.

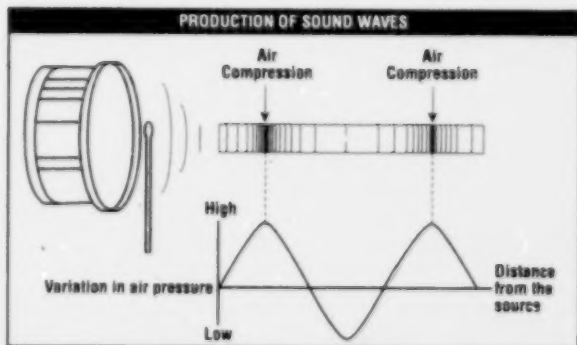


FIGURE 2. Production and transmission of sound waves.

These pressure fluctuations are sound waves which travel through the air at a speed which depends on the physical properties (pressure, temperature, etc.) of the air. The speed of sound varies from one medium to another.

Table 1: Approximate speed of sound in different materials

MEDIUM	SPEED OF SOUND (ft/s)	SPEED OF SOUND (m/s)
Air	1100	330
Soft wood	11100	3400
Water at 15o C	4700	1400
Concrete	10200	3100
Steel	16000	5000
Glass	18500	5500
Lead	3700	1200

Source: Lewis H. Bell, Industrial Noise Control, Marcel Dekker Inc. New York, 1982

m/s = meters per second. ft/s = feet per second.

The ear's hearing mechanism senses the sound waves and converts them into nerve signals which are relayed to the brain. The brain interprets the signals as sound.

4. Units and Measures of Noise

Noise (sound) has two basic properties:

- frequency or pitch
- sound pressure or loudness

Frequency

Frequency is the number of cycles of vibration a noise source completes in one second. Frequency determines the nature of sound. We hear frequency as pitch. Low pitched or bass sounds are low frequency sounds. High-pitched or treble sounds are high frequency sounds.

Frequency is measured in hertz (Hz) units. One Hz is one cycle per second. Commonly used multiple units of Hz are:

- kilohertz (kHz): 1 kHz = 1000 Hz
- megahertz (MHz): 1 MHz = 1000 kHz

A healthy young person can hear sounds in the frequency range of 20 to 20,000 Hz. The human speech is mainly in the frequency range of 500 to 5,000 Hz.

Ultrasound and Infrasound

Sounds with frequency above 16 kHz are known as ultrasound.

Sounds with frequency below 20 Hz are known as infrasound.

Both ultrasound and infrasound are not audible to people. Some ultrasound sources can also produce audible sound.

Sound Pressure

Sound pressure is a measure of the magnitude of air pressure fluctuations produced by the sound wave. The loudness of a sound depends on the sound pressure.

Sound pressure, just like air pressure, is measured in pascal (Pa). A healthy, young person can hear sound pressure as low as 0.00002 Pa. A normal conversation produces a sound pressure of about 0.02 Pa. A gasoline-powered lawn mower produces about 1 Pa. A sound pressure of 20 Pa is painfully loud. Atmospheric pressure is about 101,000 Pa.

Decibels (dB)

Use of sound pressure as a measure of loudness involves an extremely wide range of numbers from a millionth of a Pa to hundreds of Pa. This difficulty is overcome by using the sound pressure level, measured in decibels (dB), as a measure of the loudness of sound.

The decibel scale is convenient to use. It compresses the sound pressure range of 0.00002 Pa – 200 Pa into a manageable range of decibels (0 – 140 dB). The zero of the decibel scale (0 dB) corresponds to the reference sound pressure of 0.00002 Pa; the weakest sound barely

audible to a healthy young person. This is the reason dB level of sound is often written as dB(re 0.00002 Pa).

Figure 3 compares sound pressures in pascal and sound pressure levels in decibels (dB).

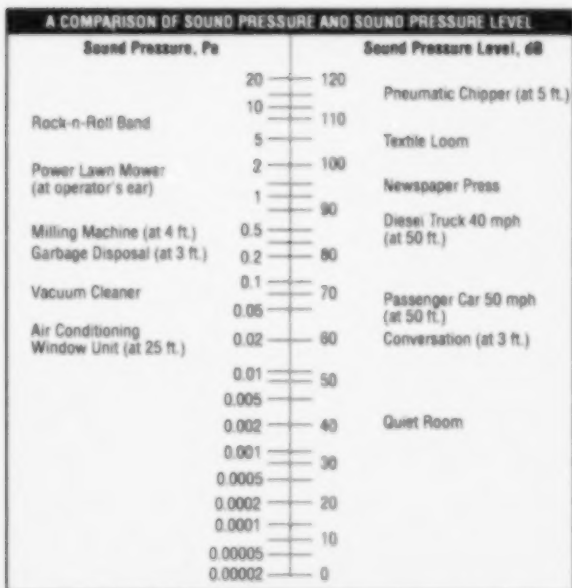


FIGURE 3: Comparison of Sound Pressure (Pa) and Sound Pressure Level (dB).

5. Units and Measures of Workplace Noise

Workplace noise is typically composed of many different sources producing many different frequencies with varying decibel levels. A complete characterization of noise would require measuring the noise level in dB at each frequency. Such data are very useful for designing noise controls but are not needed in routine measurements of workplace noise.

A-Weighted Noise Levels

For compliance with noise regulations and for assessing hearing loss risk noise level is measured as a single number using an "A" filter. The result is expressed as A-Weighted decibels or dB(A).

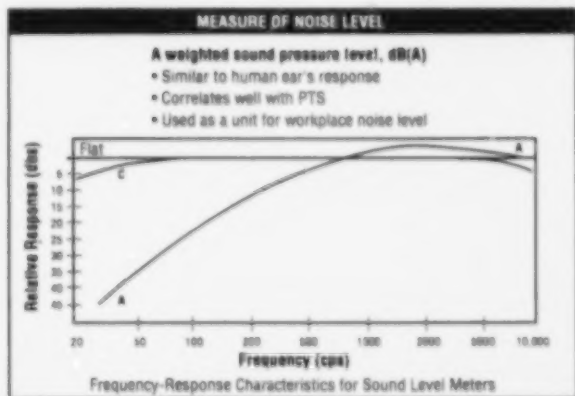


FIGURE 4: Characteristics of "A-filter" in a Sound Level Meter

A-weighting dB(A) takes into account the fact that the human ear is not equally sensitive to all of the audible sound frequencies. An A weighted filter in the noise measuring instrument, mimics the sensitivity of the human ear to sounds of various frequencies. It de-emphasizes low frequency sounds (500 Hz and below) because our ears are less sensitive to low-frequency sounds (see fig. 4). The C filter gives nearly equal weight to all frequencies. Table 2 lists examples of typical noise levels.

Table 2: Typical Noise Levels

NOISE SOURCE	dB(A)
pneumatic chipper at 1 metre	115
hand-held circular saw at 1 metre	115
textile room	103
newspaper press	95
power lawn mower at 1 metre	92
diesel truck (50 km per hour at 20 metres)	85
passenger car (60 km per hour at 20 metres)	65
conversation at 1 metre	60
quiet room	40

Sound Pressure Level and Sound Energy

The sound pressure level is related to the sound energy entering the ears of exposed persons. Table 3 gives some useful relationships between changes in decibel level and corresponding changes in the sound energy.

**Table 3: Sound Pressure Level and Sound Energy:
Basic Rules**

CHANGE IN dB	CHANGE IN SOUND ENERGY
3 dB increase	Sound energy doubled
3 dB decrease	Sound energy halved
10 dB increase	Sound energy increased by factor of 10
10 dB decrease	Sound energy decreased by factor of 10
20 dB increase	Sound energy increased by factor of 100
20 dB decrease	Sound energy decreased by factor of 100

Addition of Sound Pressure Levels

Knowing how to add sound pressure levels helps us determine overall sound pressure level due to multiple sources provided, we know the levels of each source. Table 4 can be used for adding sound pressure levels.

Table 4: Addition of Decibels	
NUMERICAL DIFFERENCE BETWEEN TWO NOISE LEVELS [dB(A)]	AMOUNT TO BE ADDED TO THE HIGHER OF THE TWO NOISE LEVELS [dB OR dB(A)]
0	3.0
0.1 - 0.9	2.5
1.0 - 2.4	2.0
2.4 - 4.0	1.5
4.1 - 6.0	1.0
6.1 - 10	0.5
10	0.0

Step 1: Determine the difference between the two decibel levels to be added.

Step 2: Find the number [dB or dB(A)] corresponding to this difference in the right hand column of the table.

Step 3: Add this number to the higher of the two decibel levels.

Example:

A machine produces an 85 dB(A) noise level in a room. What will the noise level be if a similar machine operates by the side of the first one?

This involves adding 85 dB(A) and 85 dB(A).

CAUTION: The sum is not 170 dB(A) because decibel is a logarithmic unit. Rules from Table 4 apply for such numbers.

Step 1: Difference between the two noise levels is 0 dB

Step 2: From the right hand column of Table 3, we find that the number to be added to the higher of the two levels is 3 dB

Step 3: Add $3 + 85 = 88$ dB(A)

The net noise level due to two machines is 88 dB(A).

What will the net noise level be if a third machine is added?

Step 1: Difference between the two noise levels is 3 dB ($88 - 85$)

Step 2: From the right-hand column of Table 3, we find that the number to be added to the higher of the two levels is 1.5 dB(A)

Step 3: Add $1.5 + 88 = 89.5$ dB(A)

The overall noise level is now 89.5 dB(A).

Continuous, Variable, Intermittent and Impulse Noise

A noise is called continuous noise when its level remains constant and steady over a given time period. The noise from fans, compressors and other constantly running machines are continuous noise.

If the level of noise varies with time, the noise is called variable noise.

Noise is called intermittent if there are periods of relative quiet mixed with the noise. Most manufacturing noise is variable or intermittent.

Impulse or impact noise is a very short burst of loud noise followed by a period of quiet. Examples of impulse noise include gun shots, hammering and a punch press.

Impact/impulse noise events last for less than one second and are separated from the next event by at least half a second.

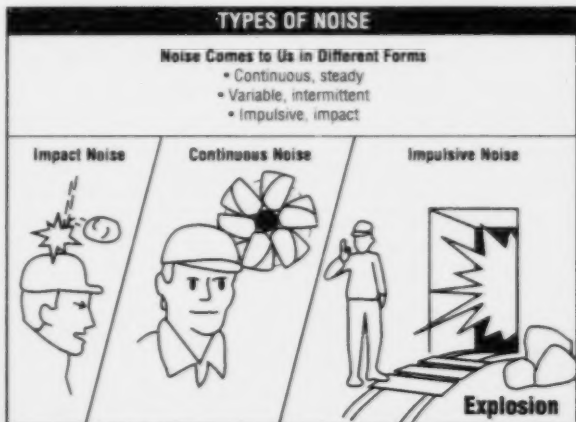


FIGURE 5: Types of Industrial Noise

6. Sound Power

Power is defined as energy produced per second. Sound power is a measure of the noise producing capacity of a machine or other equipment. A noise source, such as a compressor, a chain saw, a jackhammer, or a drum, has constant sound power that does not change if the source is placed in a different environment.

The unit of power is a watt (W). An average whisper generates a sound power of 0.0000001 W, a truck horn 0.1 W, and a turbo jet engine 100,000 W.

Like sound pressure, sound power is generally given as sound power levels in decibel (dB).

Relationship Between Sound Pressure Level and Sound Power Level

The sound power of a noise source can be used to calculate the expected sound pressure level at locations around the source. This calculation requires detailed information about the noise source's environment.

Manufacturers can often provide the sound power of their machines and equipment. Such data are helpful in selecting quieter (low sound power) machines and also in determining noise exposures of machine operators and other employees in the vicinity. There are a number of international standards for machinery noise labeling.

Measures of Workplace Noise

1. Workplace Noise Level
2. Noise Exposure Level of an Employee
3. Relationship Between Noise Exposure Level and Noise Level
4. Time Weighted Average (TWA) Noise Exposure Level
Comparison: 3dB and 5dB Exchange Rates
5. Evaluation of Noise Exposure Level

Measures of Workplace Noise

1. Workplace Noise Level

Workplace noise level is the noise level in dB(A) at a given location, at a given time. In general, noise level varies from one location to another. Also, noise level may vary with time as noisy machines and processes go on and off. Workplace noise level is measured using a sound level meter (see Section IV: Instruments and Methods of Measuring Noise)..

2. Noise Exposure Level of an Employee

Noise exposure level is the average of daily noise levels experienced by an employee. Noise exposure level depends on:

- workplace noise levels during a work shift
- durations of exposure to different noise levels

Noise Exposure Level is Most Important Measure Because:

- risk of hearing loss depends on the noise exposure level and the duration (years and months) of noise exposure; and
- noise regulations set exposure limit in terms of noise exposure level of individuals - permitted exposure time for various noise levels.

3. Relationship Between Noise Exposure Level and Noise Level

Noise exposure level is the same as the workplace noise level if an employee works at the same location during the entire work shift, and the noise level at that location remains steady.

However, if an employee works or moves in areas of varying noise levels, the noise exposure level is the net result of many different levels of exposure over varying durations of time. In such exposure situations, time weighted average exposure level is used as a measure of the noise exposure level.

4. Time Weighted Average (TWA) Noise Exposure Level

Time weighted average (TWA) noise exposure level is the average daily noise exposure of an employee, generally calculated using an 8-hour work shift. Two different methods are used to determine the TWA.

1. The Equal Energy Principle (the 3 dB rule): This method is based on the equal energy principle and is known as the 3 dB rule. The 3 dB exchange rate or the 3 dB doubling rate. In this method, allowed exposure time is halved for every 3 dB increase in noise level. For example, 93 dB(A) exposure for 4 hours is equivalent to 90 dB(A) exposure for 8 hours. The underlying principle of this method is that hearing damage depends on the total energy entering the ears. The TWA obtained using this method is known as L_{eq} . This is the method used by the international community and many Canadian provinces.
2. The 5 dB rule: This method uses a concept introduced by the OSHA (Occupational Safety and Health Administration, USA). In this method, allowed exposure time is halved for every 5 dB increase in noise levels. Thus, 95 dB(A) exposure for four hours is equivalent to 90 dB(A) exposure for 8 hours. Sometimes, the TWA obtained by using 5 dB rule is also expressed as LOSHA

Comparison: 3-dB and 5-dB Exchange Rates (Rules)

- When noise level is steady throughout the work shift, the time weighted average is the same for both the 3dB and 5 dB rules.
- The exchange rate (3 dB or 5 dB) has implications in compliance with regulated noise exposure limits.
- The 3-dB rule is more protective compared to the 5 dB-rule.
- For variable or intermittent noise, the 3 dB rule gives higher Leq than TWA in 5 dB rule.
- For the same workplace noise, the 5 dB rule may indicate compliance with the exposure limit while the 3 dB rule will show that the exposure limit has been exceeded (see Table 5 and Figure 6).

Table 5 compares TWA noise exposure levels using the 3 dB and 5 dB rules for selected noise levels and exposure times.

Table 5: Comparison of TWA noise exposure levels using the 3 dB and 5 dB rules			
WORK PLACE NOISE LEVEL DB(A)	EXPOSURE TIME HOURS	EIGHT-HOUR TWA (3 DB RULE) DB(A)	EIGHT-HOUR TWA (5 DB RULE) DB(A)
90	8	90	90
95	4	90	92
100	2	90	94
105	1	90	96

5. Evaluation of Noise Exposure Level

Noise exposure level can be determined in two ways:

1. By calculating the TWA noise exposure level. In order to do this calculation the levels of noise for the entire work shift and exposure duration for each noise level must be known (see Table 6 and Figure 6).
2. By measuring the actual noise exposure level using a noise dosimeter (see Section IV: Instruments and Methods of Measuring Noise).

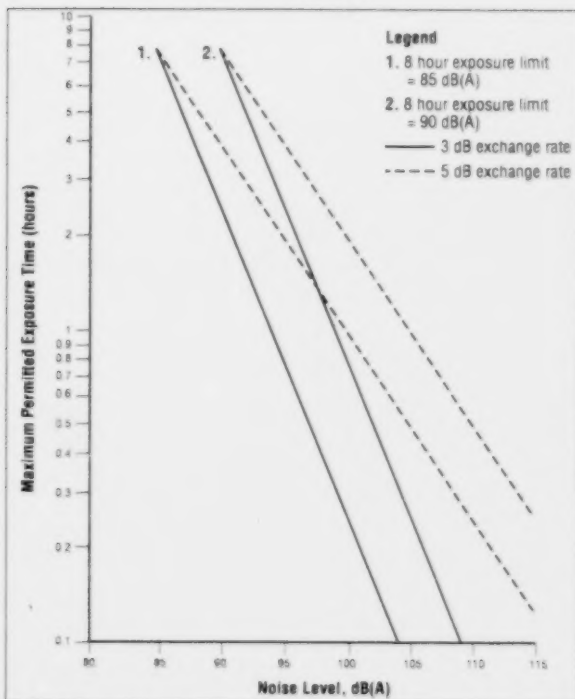


FIGURE 6: Noise Exposure Limits in 3dB and 5dB Rules

Table 6: Eight hour equivalent noise exposure levels for selected noise levels and exposure durations

NOISE LEVEL dB(A)	8 HOUR EQUIVALENT NOISE EXPOSURE LEVEL, L_{eq} dB(A) FOR EXPOSURE DURATIONS (HOURS) OF:							
	1 HOUR	2 HOURS	3 HOURS	4 HOURS	5 HOURS	6 HOURS	7 HOURS	8 HOURS
85	76	79	81	82	83	84	84	85
88	79	82	84	85	86	87	87	88
90	81	84	86	87	88	89	89	90
93	84	87	89	90	91	92	92	93
95	86	89	91	92	93	94	94	95
96	87	90	92	93	94	95	95	96
99	90	93	95	96	97	98	98	99
100	91	94	96	97	98	99	99	100
102	93	96	98	99	100	101	101	102
105	96	99	101	102	103	104	104	105

Example: An employee works for 2 hours in an area where the noise level is 99 dB(A). From the row corresponding to 99 dB(A) noise level and the column corresponding to 2- hour exposure, the 8-hour L_{eq} of the employee is 93 dB(A).

Instruments and Methods of Measuring Noise

1. Identifying Noise Problems

2. Planning Noise Measurement

3. Selecting Noise Measuring Instruments

Sound Level Meter

Integrating Sound Level Meter

Noise Dosimeter

Octave Band Analyzers

4. Effect of Environmental Conditions on Noise Data

Correction for Background Noise

5. Conducting Noise Measurements

Noise Survey

Measuring Equivalent Noise Level Using
an Integrating Sound Level Meter

Noise Dosimetry

Measuring Impulse/Impact Noise

6. Documenting Noise Data

Instruments and Methods of Measuring Noise

This section briefly outlines the steps involved in noise measurement. For further details, the reader should consult the current version of the Canadian standard CSA107.56 or American National Standard ANSI S12.19.

The most important measures of workplace noise are:

- Workplace noise level
- Personal noise exposure of individual employees.

In addition, frequency analysis of noise may be needed to design engineering controls.

1. Identifying Noise Problem

The first step is to determine whether or not noise is a potential problem in the workplace. A walk-through survey helps in making this decision.

Noise measurement data from studies in similar situations are very helpful in assessing the potential noise problem. The "Noise Levels Data Base" produced by CCOHS provides a collection of measured noise levels for a wide range of industrial situations. Table 7 shows an example of noise levels in a steel foundry as obtained from the above database.

Table 7: Examples of Typical Noise Levels	
ACTIVITY	NOISE LEVEL, dB(A)
Air jets for core blowout	105 - 110
Pneumatic core forming machine	110
Air blow off: molding and core making	100 - 120

Source: CCOHS Noise Levels Database

2. Planning Noise Measurement

- UNDERSTAND operations within the workplace where noise measurement is being planned.
- OBTAIN a copy of previous noise surveys (if any).
- KNOW applicable noise regulations and compliance requirements.
- UNDERSTAND the purposes of measurement: compliance with noise regulations, hearing loss prevention, noise control, community annoyance etc.
- IDENTIFY sources of noise, and the times when the sources are operating.
- FAMILIARIZE yourself with the temporal patterns of noise – continuous, variable, intermittent, impulse.
- IDENTIFY locations of exposed persons.
- SELECT appropriate instrumentation.

The initial measurements are generally noise surveys.

The purpose of noise survey is to determine:

- whether or not a noise problem exists,
- whether or not further measurements are needed, and
- whether or not there is a need for hearing protection.

The next step is to determine the personal noise exposure levels of employees. Noise survey data can be used to determine employee exposure provided that the workplace noise remains steady. If the workplace noise level varies throughout the day, or the worker spends time in areas with varying noise levels, noise dosimetry is necessary.

Example

In a bottle washing and filling facility, the noise levels vary over the work shift. Instantaneous noise measurements were taken at one person's work station. Noise level measurements ranged from 63 to 114 dB(A) during the day. In general, noise levels in the plant fell into two ranges: 90 to 96 dB(A) and 104 to 107 dB(A). This information strongly suggested that there was a potential for excessive noise exposure of employees. An employee was asked to wear a noise dosimeter over a full eight-hour work shift. At the end of the shift, the noise dosimeter indicated a 270% dose and TWA noise exposure level of 97 dB(A). The dosimeter was set for 5 dB exchange rate. This indicates immediate need for noise control measures.

3. Selecting Noise Measuring Instruments

Commonly used instruments for measuring noise are:

- sound level meter (SLM)
- integrating sound level meter (ISLM)
- noise dosimeter
- octave band analyzer

It is important to understand how to calibrate and operate the measuring instrument. The user's manual provided by the instrument manufacturer should provide this information. Table 8 provides some tips for instrument selection.

TABLE 8. TIPS FOR INSTRUMENT SELECTION

Type of Measurement	Appropriate Instruments (in order of preference)	Result Obtained	Comments
Personal noise exposure	1) Dosimeter	Percentage dose and equivalent sound level in dB(A)	Most accurate for personal noise exposure
	2) ISLM*	Equivalent sound level in dB(A)	If the subject is mobile, it may be difficult to determine a personal exposure, unless work can be easily divided into defined activities.
	3) SLM**	Sound level in dB(A)	If noise level varies considerably, it is difficult to determine average exposure. Only useful when work can be easily divided into defined activities and noise level is relatively stable all the time.
Noise level generated by a particular source	1) SLM**	Sound level in dB(A)	Measurement should be taken 1 to 3 metres from source (not directly at the source).
	2) ISLM*	Equivalent sound level in dB(A)	Particularly useful if noise is highly variable. It can measure equivalent sound level over a short period of time (1 minute).
Impulse survey	1) Impulse SLM	Sound level in dB(A)	To produce a noise map of an area take measurements on a grid pattern.
	2) ISLM*	Equivalent sound level in dB(A)	For highly erratic noise.
Impulse noise	1) Impulse SLM	Peak sound pressure level in dB	To measure the peak of each impulse.
* ISLM stands for Integrating Sound Level Meter ** SLM stands for Sound Level Meter			

Sound Level Meter (SLM)

A sound level meter (SLM) measures the instantaneous sound pressure level at a particular location. All SLMs must meet the specifications defined in ANSI S1.4-1983, *Specifications for Sound Level Meters*, a standard of the American National Standards Institute (ANSI 1983). This standard sets accuracy and performance criteria for two types of SLMs:

Type 1: Precision sound level meters

Type 2: General purpose sound level meters

Any SLM that is less accurate than a Type 2 should not be used for workplace noise measurement. A Type 2 SLM is sufficiently accurate for industrial field evaluations. The more accurate and much more expensive Type 1 SLMs are primarily used in engineering, laboratory and research work.

An A-weighting filter is generally built into all SLMs and can be switched ON or OFF. Some Type 2 SLMs provide measurements only in dB(A), meaning that the A-weighting filter is ON permanently.

For workplace noise level measurements, readings are taken at "SLOW" response settings. The response rate is the time period over which the noise level reading is averaged. At SLOW response setting the averaging time is 60 seconds.

Sound level meters are used for the following types of measurements:

- To spot check noise levels
- To identify noise sources
- To evaluate the effectiveness of noise controls
- To estimate employee noise exposure when a noise dosimeter is unavailable

Integrating Sound Level Meter (ISLM)

An integrating sound level meter (ISLM) is a hand-held instrument like the SLM. It measures equivalent sound levels averaged over a measurement period at a particular location. It yields a single reading of a given noise, even if the actual sound level of the noise changes continually with time. It uses a pre-programmed exchange rate with a time constant that is equivalent to the SLOW setting on the SLM.

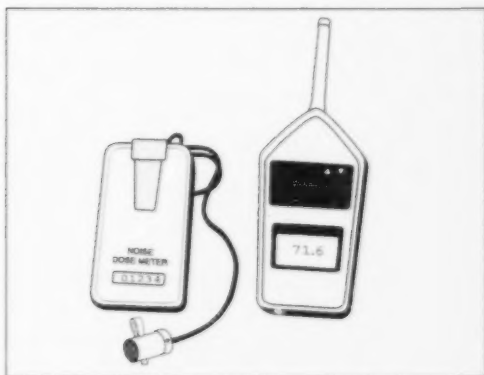


FIGURE 7: Dosimeter Sound Level Meter

Noise Dosimeter

A noise dosimeter is a small, lightweight device that clips to a person's belt with a small microphone that fastens to the collar, close to the ear. The dosimeter stores noise level information and carries out an averaging process. It is useful in industries where noise level varies during the work shift and/or where employees work at different locations with varying noise levels.

Noise dosimeters must meet the requirements for a Type 2 instrument as specified by ANSI S1.25-1991, Specification for Personal Noise Dosimeters, or another standard prescribed in the health and safety legislation applicable to the workplace.

A noise dosimeter requires the following settings:

1. **Criterion Level:** exposure limit for 8 hours per day, five days per week. The criterion level is 90 dB(A) for many jurisdictions, 85 dB(A) for some and 87 dB(A) for Canadian federal jurisdictions.

2. **Exchange Rate:** 3 dB or 5 dB as specified in the applicable noise regulation.

3. **Threshold:** noise level limit below which the dosimeter does not accumulate noise dose data.

Check applicable noise regulations for the required dosimeter settings.

A noise dosimeter measures the TWA (or Leq) noise exposure level and the percent noise dose for the time it is worn. If a person has received a noise dose of 100% during a work shift, the noise exposure level is at the maximum permitted. For example, with a criterion level of 90 dB(A) and 3 dB exchange rate, an eight-hour exposure to 90 dB(A) gives a 100% dose. A four-hour exposure to 93 dB(A) is also a 100% dose, whereas an eight-hour exposure to 93 dB(A) is 200% noise dose.

Octave Band Analyzers

An octave band analyzer is a set of filters which are either built into a SLM or attached externally. Such filter sets are identified by their geometric mean frequencies: 31.5, 63, 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz. Table 9 is an example of the data obtained by using an octave band analyzer. Acoustic engineers use octave band analyzers to:

- determine the feasibility of noise controls, and
- evaluate the effectiveness of hearing protection

For compliance with noise regulations, we need an A-weighted sound level [dB(A)] measured using a Type 2 SLM with the slow response setting. An octave band analyzer is not needed for compliance measurements.

Table 9: Example of an Octave Band Analysis

OCTAVE BAND CENTRE FREQUENCY	SOUND LEVEL
<u> HZ </u>	<u> dB </u>
31.5	85
63	91
125	99
250	98
500	97
1000	98
2000	99
4000	101
8000	98

Source: Noise Levels data base, CCOHS, Record #503, Drilling Machine Operator, mining Industry

4. Effects of Environmental Conditions on Noise Data

Environmental conditions affect the accuracy of noise data. Table 10 summarizes such effects.

TABLE 10. EFFECT OF ENVIRONMENTAL CONDITIONS ON INSTRUMENT PERFORMANCE

Environmental Condition	Effect	Precaution
Temperature	Very high or very low temperature may affect the accuracy of the noise data.	CHECK the specifications in the user's manual of the instrument. USE within the specified temperature range. Generally the instruments perform over a wide temperature range, e.g., -20°C to -60°C .
Humidity	Excessively high humidity levels may affect the performance of the electronic components of the instruments.	CHECK the user's manual for acceptable humidity range. AVOID storing the instrument in areas where vapour may condense on the instrument.
Atmospheric Pressure	Atmospheric pressure affects the instrument's calibration.	Small variations in atmospheric pressure do not cause significant change. APPLY correction for measurements in locations where atmospheric pressure is significantly different than standard.
Wind or dust	Wind or dust blowing across a microphone may cause errors in the measurement.	USE windscreens to cover the microphone in areas with considerable air movement or dust. Windscreens are available from manufacturers of sound level meters.
Background noise	A background noise that is comparable to the machine noise will affect the noise level data.	APPLY correction if the measured noise level is within 10 dB of the background noise level. USE Table 10 to apply correction for background noise.

Reflecting surfaces	The presence of reflecting surfaces such as metal and concrete increase the noise level. The effect is significant when reflecting surfaces are close to the source.	MINIMIZE the effect of reflected noise by: 1. placing the microphone close to the noise source, and 2. Covering reflecting surfaces with sound absorbing material.
Electro-magnetic field	Electromagnetic fields from arc welding, heat sealers, induction furnaces or other sources may cause faulty readings.	AVOID using sound level meters or dosimeters near sources of intense electromagnetic fields. CONSULT the user's manual to ensure that the measuring instrument is shielded from the effects of electromagnetic fields.
Vibration	Vibration affects the microphone's response to noise resulting in faulty readings.	ISOLATE the sound level meter from vibration while making noise measurements.

Correction for Background Noise

Background noise may influence the measured noise level. In order to apply background noise correction, two readings of the noise level are taken one with the noise source on and the other with the noise source off.

Table 11 can be used to determine the actual noise level due to the source.

Table 11: Background Noise Level (dB(A))	
TOTAL NOISE LEVEL BACKGROUND NOISE LEVEL (DB(A))	SUBTRACT FROM TOTAL NOISE LEVEL TO GET NOISE LEVEL DUE TO SOURCE, (DB(A))
8 - 10	0.5
6 - 8	1
4.5 - 6	1.5
4 - 4.5	2
3.5	2.5
3	3

Example: Total noise level is 97 dB and the background noise is 90 dB. To determine the noise level due to the source:

Step 1: Find difference: $97 - 90 = 7 \text{ dB(A)}$

Step 2: Find correction: 1 dB(A)

Step 3: Determine noise level due to the source:

$97 - 1 = 96 \text{ dB(A)}$.

When the difference between the overall noise level and the background noise level is 10 dB(A) or more no correction is needed.

5. Conducting Noise Measurements

Noise Survey

A noise survey involves spot measurements using a SLM to determine the need for a complete noise exposure evaluation.

A noise survey enables identification of:

- areas and jobs where employees are likely to be exposed to harmful noise levels,
- employees who might be exposed to unacceptable noise levels,
- employees for whom personal noise dosimetry may be needed,
- machines and equipment which generate harmful levels of noise, and
- noise control options to reduce noise exposure.

Tips for Conducting a Noise Survey

READ the user's manual of the measuring instrument and follow the recommended operating and calibrating instructions.

SELECT desired SLM settings. With most SLMs, the readings can be taken on either SLOW or FAST response. The response rate is the time period over which the SLM averages the sound level before displaying it on the readout. Workplace noise level measurements should be taken with the SLOW response setting selected.

CALIBRATE the SLM before and after each use.

IDENTIFY locations for measurement on the floor plan and write down the noise levels measured at these locations. This will help identify problem areas for further investigation.

DRAW a reasonably accurate sketch showing the locations of workers and noisy machines.

MEASURE the noise level at a suitable number of locations around the area and note the noise level on the sketch.

PRODUCE a noise map by drawing lines on the sketch between points of equal noise level (see figure 8).

POSITION the microphone as close as possible to the ears of the employee for whose benefit the noise level measurements are being taken.

AVOID shielding between the noise source and the microphone. The employee need not be present during the measurement.

TAKE measurements with the SLM held at arm's length at the ear height for those exposed to the noise. With most SLMs it does not matter how the microphone is pointed at the source.

TAKE as many measurements as possible. The more measurements taken, the more accurate is the survey.

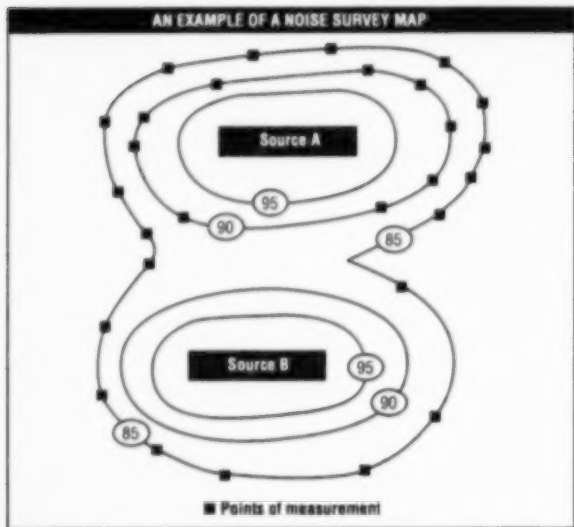


FIGURE 8. Noise map

A standard SLM takes only instantaneous noise measurements. This is sufficient in workplaces with continuous noise levels. In workplaces with impulse, intermittent or variable noise levels, an ISLM makes it possible to determine average noise over a desired time or entire work shift.

Measuring Equivalent Noise Level Using an Integrating Sound Level Meter (ISLM)

An ISLM is used to measure the equivalent noise level averaged over the measurement period which can range from a few minutes to an entire work shift. In this respect an ISLM is similar to a dosimeter being used as an area monitor. An ISLM does not provide personal exposure level because it is not worn on person. It gives

equivalent sound levels at a particular location, measured using a pre-programmed exchange rate and a SLOW response setting.

Noise Dosimetry: Work Shift Sampling

Noise dosimetry is needed if the noise survey data indicates that some employees are likely to exceed the noise exposure limit set by regulations or employer's guidelines. Noise exposure levels of potentially exposed persons are measured using noise dosimeters.

The selected employees wear dosimeters during all or part of the shift. The reliability of the noise data will depend on the employee cooperation in the proper use of the dosimeter.

Helpful Tips for Ensuring Employee Cooperation

BE HONEST about the use of the noise level data being collected.

INFORM the employees about the purpose of measurement.

EXPLAIN the importance of accuracy in assessing the need for noise control.

EMPHASIZE the importance of wearing the dosimeter at all times during the measurement period.

EXPLAIN the consequences of tampering with the microphone shouting in it, using it to knock doors, etc.

BE FRIENDLY with employees

Helpful Tips for Noise Dosimetry

READ the user's manual to ensure proper use of the dosimeter.

SELECT dosimeter settings as required by the noise regulations applicable to the workplace.

CONSULT relevant ANSI, CSA or ISO standards regarding measurement procedures if there are no regulatory guidelines.

CHECK calibration before giving out dosimeters and again after the end of the measurement period.

NOTE the names of employees and their jobs.

RECORD the start and stop times of the dosimeters.

RECORD dosimeter readings. Clearly identify the noise source, tasks performed by the employee duration of dosimeter use, percent dose and the TWA noise exposure for the entire work shift.

Understanding Noise Data from a Dosimeter

Noise dose (%): Noise dose gives the wearer's noise exposure compared to the exposure limit.

- A 100% dose indicates that the wearer has been exposed to maximum permissible noise exposure limit.
- Less than 100% indicates that the exposure was below the maximum permissible limit.
- More than 100% indicates that the noise exposure exceeded the maximum permissible limit.

Table 12 shows how to convert percent noise dose to equivalent sound level (L_{eq}) for an 8-hour work shift assuming a 90 dB(A) exposure limit and a 3 dB exchange rate.

Table 12: Converting Percent Noise Dose to Equivalent Sound Level (Leq)

NOISE DOSE (%)	L_{eq} IN dB(A) FOR 8-HOUR WORK SHIFT
10	80.0
20	83.0
50	87.0
75	89.0
100	90.0
110	90.4
120	90.8
150	91.8
175	92.4
200	93.0

Noise level: Most dosimeters give readings of maximum, minimum and equivalent noise level.

Time history: Modern dosimeters have data storage capability. Such data can be transferred to a personal computer and printed to analyze the time-history of noise exposure. If the dosimeter is worn for only part of the work shift, care must be taken when determining average noise exposure level for the entire work shift.

Measuring Impulse/Impact Noise

Measurements of impulse or impact noise depend on the guidelines and standards in force. The noise measuring equipment must have the capability to measure impulse/impact noise. Normally measurements of either peak noise levels together with the actual number of peaks, or percentage dose, or equivalent sound levels are required.

Some noise regulations recommend impulse noise exposure limits as a maximum number of impacts/impulses for a given peak pressure level (dB). This is generally true for noise regulations based on the 5 dB exchange rate. Measuring peak pressures may be most appropriate where there is little background noise, as on an outdoor rifle range.

In industrial settings, there is usually considerable background noise in addition to the impulse noise. In such cases, provided that a 3 dB exchange rate is used, dosimeters or ISLMs which are sufficiently sensitive to respond to peaks may be appropriate. One can account for all of the noise, continuous and impulse, in the one measurement.

6. Documenting Noise Data

The noise data should be documented along with other relevant information such as:

Employee Data

- Employee name
- Job title
- Task performed during the measurement
- Source of noise
- Location of employees relative to noise source
- Measuring instruments used
- Duration of measurement
- Use of hearing protection

Workplace Data

- Shape, size, and layout of the room
- Layout of workstations, equipment and machinery
- Floor, wall, and furniture materials, and any acoustical lining
- Presence of acoustical barriers and enclosures
- Background noise from sources outside the workroom

Machine, Equipment and Work Process Data

- Source(s) of noise: machine, equipment, work practice
- Physical condition of machines and equipment
- Existing noise controls: mufflers, enclosures, barriers, etc.
- Type of noise: continuous, intermittent, impulse

Work Practice Data

- Operator position with respect to machine (noise source)
- Use of hearing protection
- Duration of exposure
- Operating conditions: speed, type of work, contact with workpiece, etc.

Noise Measurement Data

- Instrument used
- Calibration status
- Duration of measurement
- Type of noise data: SPL, Leq, dose (%), max. min. peak
- Octave band analysis

Following is an example of a noise data reporting form. This form was developed for recording noise data for the CCOHS Noise Levels database.

Noise Levels Recording Form

INDUSTRY GROUP: _____ DATE: _____

EMPLOYEE'S NAME: _____

JOB OPERATION: _____

OCCUPATION: _____

EXPOSURE DURATION PER DAY: _____

NOISE SOURCE: _____

SOUND MEASURING EQUIPMENT USED: _____

NOISE TYPE: ☐ Continuous ☐ Intermittent ☐ Impulse

HEARING PROTECTION USED: _____

ENGINEERING CONTROLS APPLIED: _____

MEASUREMENT DATA

Location of Measuring Device	Sound Level dB(A)				Dosimeter Data With exchange rate 3 dB 5 dB		
	One Shot	Min	Max	Leq	Dose%	Leq/ TWA	Duration
1. _____							
2. _____							
3. _____							
4. _____							
5. _____							

OCTAVE BAND ANALYSIS:

Noise level in dB at octave band centre frequencies (Hz)

	31.5	63	125	250	500	1000	2000	4000	8000
1. _____									
2. _____									
3. _____									
4. _____									
5. _____									

SURVEYED BY: _____

Section V

Evaluating the Risk of Noise Induced Hearing Loss

1. Types of Hearing Loss

Permanent Hearing Loss

Hearing Loss Due to Aging

Other Causes of Hearing Loss

2. Measures of Hearing Loss

Hearing Disability

3. Relationship Between Noise Exposure and Hearing Loss

Evaluating the Risk of Noise Induced Hearing Loss

1. Types of Hearing Loss

Permanent Hearing Loss

Permanent hearing loss, also known as permanent threshold shift (PTS), is the main concern related to occupational noise exposure. Following are the typical characteristics of noise-induced permanent hearing loss:

- All exposed persons are not equally susceptible to noise induced hearing loss. Some highly susceptible persons may notice hearing loss as result of moderately loud noise exposure for only a few years. However, as noise exposure continues more and more people are affected.
- In the initial stages, hearing loss is most pronounced at 4000 Hz. It spreads to other frequencies as noise level and/or exposure time increases.
- Noise induced hearing loss is "sensory-neural hearing loss" because noise destroys the hearing organs in the inner ear.
- Hearing loss worsens as noise exposure continues month-after month-and year-after-year.
- Hearing impairment is not noticeable until it is substantial enough to interfere with routine activities.
- Hearing damage cannot be cured by medical treatment.
- When noise exposure stops, the affected person does not regain the lost hearing sensitivity. However, noise induced hearing loss does not get any worse.

- As a person ages, hearing may worsen because "age-related hearing loss" adds to the existing noise induced hearing loss.
- Both ears are equally affected except in cases when one ear is exposed to a higher noise level than the other.
- Hearing loss is a cumulative process; both level of noise and exposure time are important factors.

Hearing Loss Due to Aging

Hearing sensitivity naturally declines as people become older. Like noise-induced hearing loss, everyone is not affected equally. Age-related hearing loss adds to noise-induced hearing loss and therefore hearing ability may continue to worsen even after a person stops working in a noisy environment.

Other Causes of Hearing Loss

Exposure to ototoxic chemicals (eg. toluene, lead, manganese), certain medications and diseases may also cause hearing loss. Generally, it is not possible to distinguish hearing loss due to noise from hearing loss due to other causes. Judgement in such cases is based on the noise exposure history.

2. Measures of Hearing Loss

Hearing loss is measured as threshold shift in dB units using an audiometer. The 0 dB threshold shift-reading of the audiometer represents the average hearing threshold level of a young adult with disease-free ears. The threshold shift as measured by audiometry is the dB level of sounds of different frequencies barely audible to that individual. A positive threshold shift represents hearing loss, and a negative threshold shift means better than average hearing.

EXAMPLES OF AUDIOGRAMS

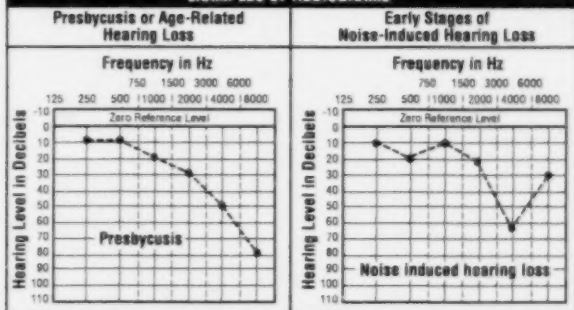


Figure 9. Examples of Audiograms

Hearing Disability

Hearing disability is a medico-legal definition of the degree of hearing loss. Several methods of calculating the percentage of hearing disability are in use. The American Medical Association (AMA/ American Academy of Otolaryngology (AAO) formula is widely accepted in North America. The current method recommended by AMA/AAO is as follows:

1. Calculate the average hearing threshold level at 500, 1000, 2000 and 3000 Hz for each ear.
2. Calculate the percentage of impairment for each ear (the monaural loss) by multiplying the amount the above average exceeds 25 dB (low fence) by 1.5. Hearing impairment is 100% for a 92 dB average hearing threshold level:

$$92 \text{ db} - 25 \text{ db} = 67 \text{ db}; 67 \times 1.5 = 100\%$$

3. The hearing handicap (binaural assessment) is calculated by multiplying the smaller percentage (better ear) by 5, adding it to the larger percentage (poorer ear), and dividing the total by 6.

Figure 13: Example of Hearing Disability Calculation

FREQUENCY, Hz	HEARING THRESHOLD LEVEL, dB	
	LEFT EAR	RIGHT EAR
500	30	15
1000	45	25
2000	60	45
3000	85	55
SUM	220	140
AVERAGE	55	35
LOW FENCE	25	25
EXCEEDS LOW FENCE	30	10
% IMPAIRMENT	45	15
DISABILITY	[(45x1 + 15x5)/6] = 20%	

The actual dollar value of compensation for a given percentage of hearing loss varies from one jurisdiction to another.

3. Relationship Between Noise Exposure And Hearing Loss

From the scientific data accumulated to date, it is possible to determine the risk of hearing loss among a group of noise exposed persons. Methods of estimating hearing loss from noise exposure data are given in the international standard ISO1999-1990 and the American standard ANSI S3.44. In order to estimate hearing loss risk using these standards, we need the following data:

- A measure of daily noise exposure level
- Duration of noise exposure (months, years)
- Age of the person

Given a noise exposed person, it is not possible to determine if hearing loss is due to noise. However, in a group of exposed persons, the percentage of population with hearing loss depends on the level of noise exposure and the duration of exposure. For higher noise exposure levels, and longer durations of exposures, a larger percentage of exposed persons will acquire hearing loss. This observation forms the basis of the calculation of noise induced hearing loss as outlined in the ISO and ANSI standards.

Figure 10 shows the percentage of a noise exposed population with hearing loss from exposure to various levels of noise. The definition of hearing loss is hearing threshold shift averaged at audiometric frequencies 500, 1000, 2000 and 3000 Hz. For simplicity, it has been assumed that all persons in the noise exposed group started working at 20 years of age. The 70 dB(A) curve represents the hearing loss risk of unexposed persons. Comparing this curve with that corresponding to 90 dB(A), we notice that a 90 dB(A) exposure limit implies accepting some hearing loss risk.

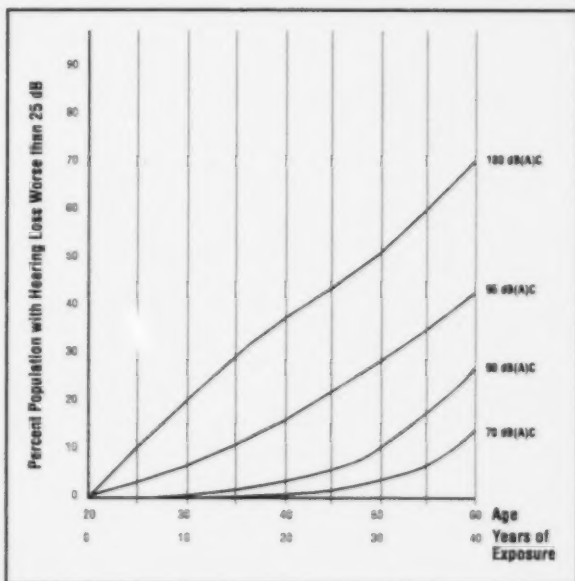


FIGURE 10. Percent of noise exposed population with hearing loss in excess of 25 dB for various noise levels and years of exposure as given by the ISO method. Hearing loss is defined as average threshold shift at 500, 1000, 2000 and 3000 Hz.



Section VI

Occupational Noise Exposure Limits

1. Noise Exposure Limits

- Exposure Limits for Impulse/Impact Noise
- Noise Exposure Limits for Extended Workshifts
- Deciding Exposure Limits for Extended Workshifts

2. Canadian and U.S. Noise Regulations

3. Synergistic Effects: Ototoxic Chemicals

4. Office Noise Levels

1. Noise Exposure Limits

Noise exposure limits are typically given as the maximum duration of exposure for various noise levels. Table 14 shows the criterion levels (exposure limit for 8-hours) and exchange rates used by different Canadian and U.S. jurisdictions.

Table 14: Noise Exposure Limits

JURISDICTION / PROVINCE	CONTINUOUS NOISE		IMPULSE / IMPACT NOISE	
	MAXIMUM PERMITTED EXPOSURE LEVEL FOR 8 HOURS: dB(A)	EXCHANGE RATE dB(A)	MAXIMUM PEAK PRESSURE LEVEL dB(PEAK)	MAXIMUM NUMBER OF IMPACTS
Canada (Federal)	87	3	—	—
British Columbia	85	3	135 dB(A)	—
Alberta	85	5	140	100
Saskatchewan	85	NS*	—	—
Manitoba	90	3	—	—
Ontario	90	5	140	100
Ontario (draft regulations)	90	3	140	—
Quebec	90	5	140	100
New Brunswick	85	5	140	100
Nova Scotia	85	5	140	100
Prince Edward Is.	85	3	140	—
Newfoundland	85	3-	—	—
Northwest Territories, Nunavut	85	5	140	140
Yukon Territory	87	3	140	90
ACGIH (TLV)+	85	3	—	—
US OSHA++	90	5	140	100

Note:

When the 3 dB exchange rate is used there is generally no separate regulation for impulse/impact noise. Equivalent noise level (L_{eq}) is used for impulse noise in the same way as that for continuous or intermittent noise. The regulations or guidelines in several jurisdictions treat impulse noise separately from continuous noise.

** Not Specified*

+ ACGIH: American Conference of Governmental Industrial Hygienists. ACGIH threshold limit values (TLV) are included here because some jurisdictions adopt TLVs as regulatory exposure limit.

++ OSHA = U.S. Occupational Safety and Health Administration

Exposure Limits for Impulse/Impact Noise

Some jurisdictions have set separate exposure limits for continuous and impulse noise. For impulse noise, a common approach is to limit the number of impulses at a given peak pressure level during a workday. The exact figures vary slightly, but generally the regulations permit 10,000 impulses at a peak pressure of 120 dB; 1,000 impulses at 130 dB; and 100 impulses at 140 dB.

Alternatively, using a 3 dB(A) exchange rate, impulse noise can be considered jointly with any continuous noise, using the permissible exposure durations.

In addition to permissible exposures, many Canadian noise regulations also include requirements for engineering controls and hearing protection. Table 15 shows an example of exposure limits for impact noise. Consult local regulation for provincial requirements.

Table 15: Example of Exposure Limits for Impact/Impulse Noise

PEAK PRESSURE LEVEL, dB	NUMBER OF IMPACTS
120	10000
125	3162
130	1000
135	316
140	100
greater than 140	0

Source: Quebec Noise Regulation

Noise Exposure Limits for Extended Work Shifts

Most standards and guidelines concerning noise exposure are based on an 8-hour work shift and also provide levels for shorter working days. When calculating exposure limits for an extended work shift such as 12 hours, one must take into account the information on health effects related to noise exposure and those related to a 12-hour shift. The final answer has to come from a study of actual work places that might have experimented with or adapted such work practices.

A change from an 8-hour shift to a 12-hour shift must consider the following issues:

- Eight-hour time-weighted noise exposure level in dB(A)
- Problems related to use of hearing protectors for such a prolonged work shift
- Combined effect of noise and the stress factors related to a 12-hour shift

Deciding Exposure Limits for Extended Work Shifts

Time-weighted average (TWA) exposure limits range from 85 dB(A) to 90 dB(A) for 8-hour work day.

The International Organization for standardization (ISO/DIS 1999/1990) recommends the use of the equal energy principle (3 dB exchange rate) in calculating the TWA for a work shift:

Limit for a given shift = $90 + 10 \log (8/T)$ where
T = duration of work shift in hours.

An alternative method, called the Brief and Scala method, is sometimes used to calculate TLV (Threshold Limit Values) for chemicals. This method is more conservative than the TWA method described above. It takes into account the increased hours of work as well as the decreased hours of recovery. Applying this method results in exposure limits which are lower than TWAs. For example, for a 12 hour shift, exposure time increases by a factor of 12/8 and recovery time decreases by a factor of 12/16. Therefore, the exposure limit should decrease by factor

$$= (8/12) \times (12/16) = 0.5$$

The exposure limits for extended shifts, based on a different method, are listed in Table 16. Although the Brief and Scala method is recommended to determine exposure to chemicals, its use for noise is not common.

For regulatory guidelines regarding extended work shifts, contact the local government department responsible for workplace health and safety regulations.

**Table 16: Examples of Noise Exposure Limits
for Extended Work Shifts**

WORK SHIFT DURATION HOURS	EXPOSURE LIMIT, Db(A)	
	USING 5 dB EXCHANGE RATE	USING 3 dB EXCHANGE RATE
8	90	90
9	89.2	89.5
10	88.4	89
11	87.7	88.6
12	87.1	88.2
13	86.5	87.9
14	86	87.6
15	85.5	87.3
16	85	87

2. Canadian and US Noise Regulations

Table 17 gives a list of federal, provincial, and territorial noise regulations in Canada and U.S.A. Since the occupational health and safety legislation is amended from time to time, please contact the local occupational health and safety department for the latest information.

Table 17: Canada and U.S. Noise Regulations

JURISDICTION	NOISE REGULATION
Canada (Federal)	Canada Labour Code, Part II, (R.S.C. 1985, c. L-2) Canada Occupational Safety and Health Regulations, (SOR/86-304), Section 7.4(1)(b)

JURISDICTION	NOISE REGULATION
British Columbia	Workers' Compensation Act Occupational Health and Safety Regulations (BC Reg 296/97 as amended), Section 7.2
Alberta	Occupational Health and Safety Act Noise Regulation (Alta. Reg. 314/81), Tables 1 & 2
Saskatchewan	Occupational Health and Safety Act, 1993 Occupational Health and Safety Regulations, 1996 [R.R.S. c.0-1.1, r.1] , Part VIII, Section 113 (1)
Manitoba	Workplace Safety and Health Act Hearing Conservation and Noise Control Regulation (Man Reg 227/94), Section 3
Ontario	Occupational Health and Safety Act Industrial Establishments (R.R.O. 1990, Reg 851) Section 139
Quebec	Act Respecting Occupational Health and Safety Regulation Respecting the Quality of the Work Environment (RRQ 1981 c.S-2.1, r.15), Division VIII, Sections 44 - 55
New Brunswick	Occupational Health and Safety Act; General Regulation (N.B. reg. 91-191), Part V, Sections 29 - 33

JURISDICTION	NOISE REGULATION
Nova Scotia	Occupational Health and Safety Act (S.N.S. 1996, c.7) Adopted the Threshold Limit Values (TLVs) set by the ACGIH in 1976.
Prince Edward Island	Occupational Health and Safety Act Occupational Health and Safety Regulation (E.C. 180/87), Part 8, Section 8.1 (uses ACGIH-TLV booklet as updated annually)
Newfoundland	Occupational Health and Safety Act Occupational Health and Safety Regulations (C.N.R. 1165/96), Section 50 (uses ACGIH-TLV booklet as updated annually)
Northwest Territories	Safety Act : General Safety Regulations (RRNWT 1990, c. S-1, R-028-93 as amended), Section 30 and 31, Schedule A, Table 1
Nunavut	The Nunavut Act (S.C. 1993, c.28) states that all laws of the Northwest Territories will apply in Nunavut
Yukon Territory	Occupational Health and Safety Act Occupational Health Regulation (O.I.C. 1986/164)
U.S.A.	OSHA: Occupational Noise Exposure Standard 29CFR 1910.95

3. Synergistic Effects: Ototoxic Chemicals

Exposure to certain chemicals (substances) is known to adversely affect hearing sensitivity. Such chemicals are known as ototoxic chemicals. Following substances are known to be ototoxic:

- Toluene
- Lead
- Manganese

The following substances are potentially ototoxic:

- Trichloroethylene
- Carbon disulfide
- Styrene
- Mercury
- Arsenic

Risk of hearing loss may be increased if employees are exposed to noise as well as any of the toxic substances. In such cases, it is advisable to reduce the exposure limit for noise as well as for ototoxic substances.

The stress related to a 12-hour shift has been studied by many researchers. There have been mixed feelings about the impact on general health of the 12-hour shift.

4. Office Noise Levels

Industrial noise regulations are intended to prevent hearing loss and use 85-90 dB(A) as an occupational exposure limit. These exposure limits are not appropriate for office work as they would interfere with speech communication and cause annoyance and stress.

There are noise guidelines for office work but there are no separate noise regulations for office environments. The Canadian Standards Association Standard Z412-M89 Office Ergonomics provides guidelines for office noise.

The objectives of the office noise guidelines are:

- to prevent interference with verbal communication
- to avoid annoyance and stress
- to minimize interference with concentration in the performance of mental work

This means that the concerns related to office noise are the effect on the ability to hear verbal conversation as well as psychological effects. Ability to hear depends on the level of sound, and psychological effects depend on the frequency and the level of sound. Therefore, for office noise both sound level and frequency are taken into consideration. A range of room criteria curves, called RC curves, are used for the purpose.

Table 18 gives the design criteria recommended in the CSA Z412-M89 standard. The numerical descriptor of the RC curve (for example 30 in RC-30) represents the speech interference level (SIL). SIL is the arithmetic average of the noise levels in the 500, 1000, and 2000 Hz.

Table 18: Room Criteria Design Goals

TYPE OF AREA	RECOMMENDED RC RANGE
Executive offices	25-30
Conference rooms	25-30
Private offices	30-35
Open-plan offices	35-40
Computer/business machines	40-45
Public circulation	40-45

Source: Canada Standards Association Standard CSA Z412-M89

The sound level of a normal conversation with a person at 1 metre distance is 60 – 65 dB(A). The office noise level has to be about 10 dB(A) lower to eliminate interference with speech communication.

Managing Workplace Noise Problems

- 1. Hearing Conservation Program Components**
- 2. Noise Monitoring: Hazard Identification**
- 3. Noise Reduction: Engineering Controls**
 - At the Source
 - Along the Path
- 4. Hearing Protection**
 - Selection of Hearing Protection
 - Advantages and Limitations of Earplugs and Earmuffs
 - Standards
- 5. Hearing Measurement**
- 6. Administrative Controls**
- 7. Employee Training**
- 8. Program Evaluation and Continuous Improvement**

Managing Workplace Noise Problems

There is no unique solution to workplace noise problems. The answer will depend on the nature of the problem. Both short-term and long-term solutions must be considered. In the short-term solution, a choice has to be made between a safe workplace (engineering controls) and safe worker (use of ear protectors). The long-term solution is, of course, a safe workplace where personal protection is not needed.

A systematic effort by management in consultation with the health and safety committee is important in achieving goals. The collaboration of employees is key to the success of a noise control program. The activities geared towards controlling noise and minimizing its health effects are collectively known as a hearing conservation program.

1. Hearing Conservation Program Components

A hearing conservation program is a guide to help management reduce the risk from hearing loss. The program must:

- clearly state its objectives;
- spell the steps to be followed and their sequence;
- assign authority and responsibility for each step; and
- carry the signature of the highest authority in the workplace.

The essential components of hearing conservation program are:

1. Noise Monitoring: hazard identification.
2. Noise Reduction: engineering controls, substitution, maintenance.
3. Hearing Protection: interim noise exposure control.
4. Hearing Measurement: audiometry.

-
5. Administrative Controls: warning signs, controlled access.
 6. Employee Training: education.
 7. Program Evaluation and Improvement: effectiveness of controls, periodic review.

Figure 8. is an example of a decision chart for managing workplace noise problems.

2. Noise Monitoring: Hazard Identification

The noise monitoring methods outlined in Section IV should be helpful in planning and conducting noise measurements. Figure 11 illustrates the use of noise data in planning a hearing conservation program. In this chart, 85 dB(A) has been used as an action level to initiate noise exposure control actions. An industry or workplace may use 80 dB(A) as an action level to ensure better protection.

FIGURE 12. NOISE MONITORING HAZARD IDENTIFICATION

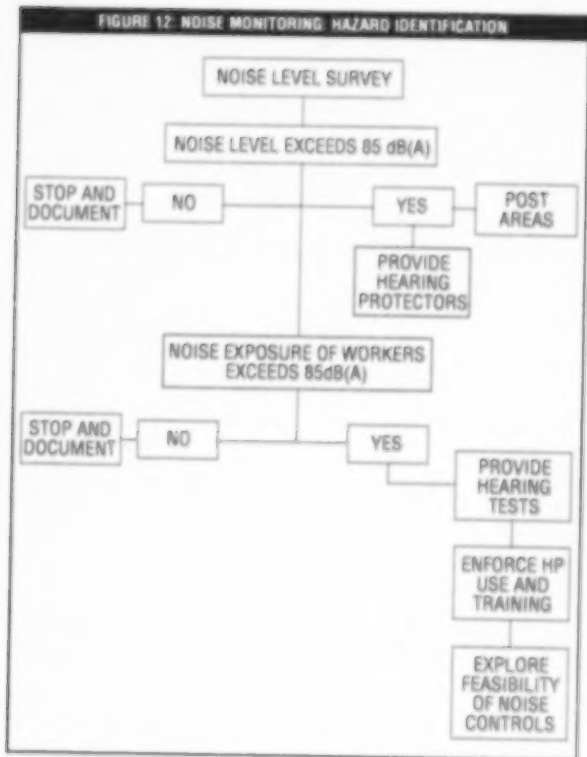


FIGURE 11. Noise assessment and noise management actions

If noise levels exceed 85 dB(A), then a noise exposure survey (dosimetry) has to be performed. This is done preferably using a dosimeter (although a SLM or an ISLM can also be used) and following the procedures in CSA Z108.56 (U.S.A.: ANSI S12.19)

While the sound level survey is a geographical one (it is done at specific locations), the noise exposure survey is done **on workers** or on **groups of workers**, so that results are directly related to actual, not potential risk.

Noise Exposure Control Options

Long-term control: The surest method of eliminating occupational hearing loss is to reduce noise levels in the workplace by using engineering controls.

Immediate control: Until noise is reduced to an acceptable level, worker exposure should be controlled by work practice changes and a hearing protection program.

3. Noise Reduction: Engineering Controls

Engineering controls are a combination of the following basic principles:

- Control at the source; and
- Control along the path.

Noise Control at the Source

Noise control options include:

- Acquire quieter machines.
- Reduce noise emissions from machines by installing noise-reducing attachment.
- Reduce noise by adequate maintenance: proper oiling, greasing, and replacement of worn out, noisy parts.

Selecting Quiet Equipment

Look for equipment that carries a low noise emission rating, preferably backed by a certifying laboratory's report and the method/standard used in measuring the noise level of the equipment.

The following guidelines are suggested for selecting quiet equipment:

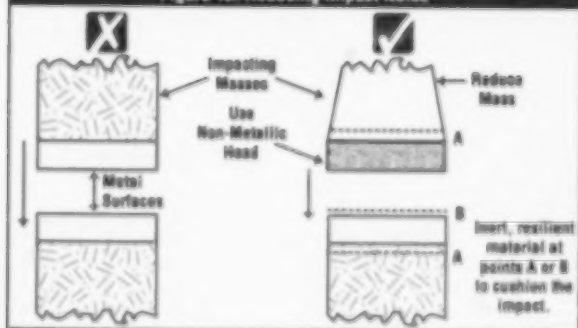
- Low-noise certification.
- Evidence of noise control design and "quiet" operation.
- "Lower" and "slower" operating characteristics.
- Comparative noise tests.
- Experience of other buyers.

Reduce Impact or Impulsive Forces

Whenever practical, the following steps can be taken to reduce noise from machines with parts that strike forcefully against other parts:

- **REDUCE** height and weight of fall.
- **CUSHION** the impact by inserting a layer of shock absorbing material.
- **USE NON-METALLIC** material as one of the impact heads to reduce resonance or ringing.
- **APPLY** a small impact force over a long period of time instead of a large force over a short period.
- **MINIMIZE** overshoot, backlash, loose play in cams, followers, gears, linkages, etc.

Figure 12: Reducing Impact Noise



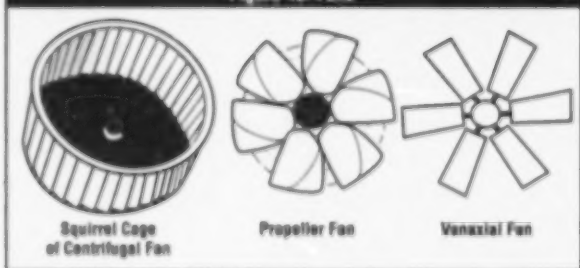
Reduce Machine Speed, Fluid Flow Velocity, and Fluid Pressure

Reducing machine speed results in smoother operation and a lower noise level.

Reducing flow velocity and pressure in liquid and gas flow systems results in quieter operation.

- **USE** large-diameter, low-speed fans rather than small-diameter high-speed fans.
- **USE** squirrel cage fans wherever possible. For a given air flow squirrel cage fans are generally less noisy than to axial or propeller type fans.
- **REDUCE** water and other fluid flow rates in pipes and plumbing systems.
- **REDUCE** air flow speed in ducts. A 50% reduction in air flow velocity may reduce ventilation noise by 10-20 dB.

Figure 13: Fans



Balance Rotating Parts

Poorly balanced rotating parts such as fans, fly wheels, pulleys, cams, shafts, etc., produce noise. This can be avoided by proper preventive maintenance of the machine.

Reduce Friction

Friction between rotating, sliding, or moving parts could be a source of noise. Remedial actions include:

- † Lubrication
- † Alignment
- † Polishing
- † Balancing
- † Avoiding eccentricity or out-of-roundness

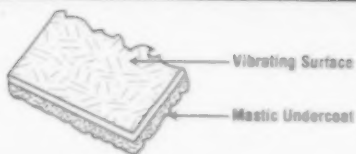
Reducing resistance in air and fluid flow

- † STREAMLINE the flow.
- † REDUCE flow velocities.
- † SMOOTHEN boundary surfaces.
- † MINIMIZE branches, turns, fittings and connectors in ducts.
- † USE long radius turns.
- † USE flared sections.
- † STREAMLINE flow in transition in flow paths.
- † REMOVE unnecessary obstacles from flow path.

Vibration Isolation

The vibration generated by rotating parts of a machine must be isolated as much as possible from the structural frame or housing of the machine. The most effective method of vibration isolation involve resilient mounting of the vibrating component on the most massive and structure-ally rigid part of the machine.

Figure 14: Vibration Damping



Mastic coating should be 2 to 3 times as thick as the vibrating surface for maximum effectiveness.

Vibration Damping Materials

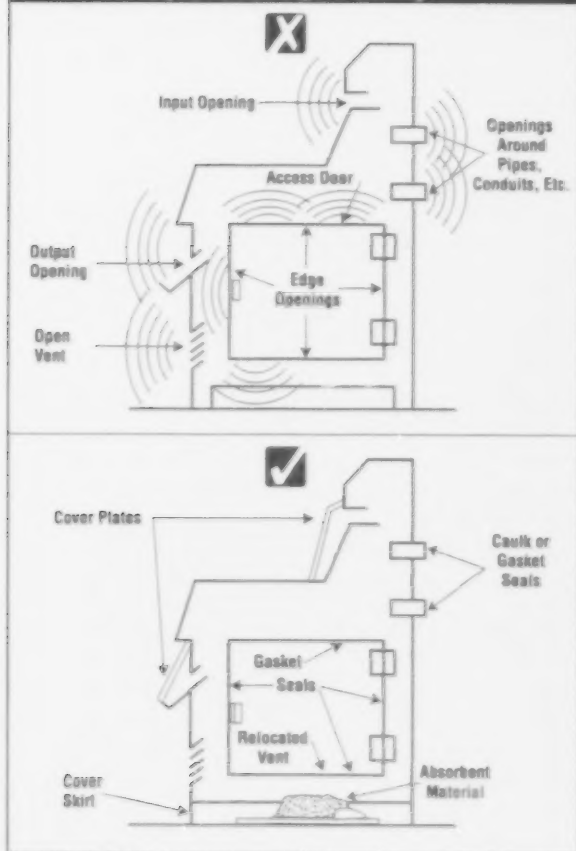
Vibrating surfaces radiate noise. Application of damping material decreases noise output of such surfaces. Damping materials dissipate the vibration energy in the form of frictional heat, which is generated by flexing, bending, and rubbing of fibres or particles of the damping materials. Damping materials are applied to the inner surface of the machine in order to preserve the appearance. Three types of damping materials are available:

1. Liquid mastic sprayed on solid materials. The most common example is automobile undercoating.
2. Rubber pads, felt, plastic foam, leaded vinyl, adhesive tapes or fibrous blankets which are glued to the vibrating surface.
3. Sheet metal viscoelastic laminates or composites which are bonded to the vibrating surface.

Reducing Noise Leakage from the Interior of Machines

- Seal all openings.
- Apply acoustic materials.

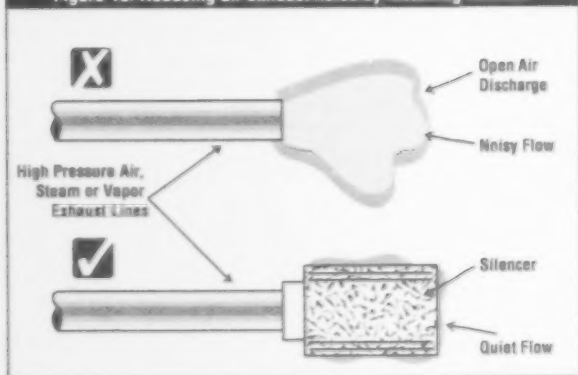
Figure 15: Reducing Noise Leakage



Mufflers

A muffler is an acoustic filter. It's performance varies with the sound frequency. A muffler reduces the transmission of sound and allows the free flow of gas. Mufflers are installed to reduce noise where large quantities of high pressure gas, liquid, steam or air are discharged into the open air.

Figure 16: Reducing air exhaust noise by installing muffler.



Selection Criteria for Mufflers

Acoustical Criterion: Noise reduction capability measured as insertion loss.

Insertion Loss (dB) =
SPL before muffler - SPL after muffler

Aerodynamic Criterion: Maximum acceptable pressure drop through the muffler.

Geometrical Criterion: Maximum allowable volume and restrictions on the shape.

Mechanical Criterion: Durability, maintenance, and environmental conditions.

Noise Control Along the Path

This involves stopping noise before it reaches the employee. Control actions include:

- Absorbing machine noise before it reaches work areas by installing enclosures, screens and shields.
- Protecting the worker from surrounding machines by providing acoustically shielded operating booths.
- Minimizing reflected noise from walls, ceilings and floors by covering them with sound-absorbing material.

For controlling noise along the path, two types of materials are used:

Sound Absorber Materials: These materials absorb sound as it passes through them. An absorptive material must have a porous structure, and are light weight, such as foam and fibrous materials.

Sound Attenuating Materials: There are non-porous, dense and heavy materials such as lead, concrete and steel. When sound impinges on these materials, it is reflected and hence, only a small fraction can pass through.

- A sound attenuation materials usually a good reflector and poor absorber.
- Sound absorbing materials are used for acoustic linings of walls and ceilings. A combination of sound absorbing and sound attenuating materials are used in designing machine enclosures.

Principles of Control

- Increase the distance from the source.
- Absorb the sound along the path.
- Deflect the sound in other direction.
- Contain the sound by placing the source inside enclosure.

Distance

In open spaces, noise should decrease 6 dB for every doubling of the distance. This does not happen indoors because of reflections from the walls, ceiling and floor. Near the source, the noise level may drop 3 - 5 dB for each doubling of the distance. Farther from the source, only a 1- 2 dB reduction may occur for each doubling of the distance.

Use of Sound Absorbing Materials

In enclosed spaces, noise exposure occurs due to noise reaching the employee directly from the noisy machine, and reflected noise from the walls, ceiling, floor and other objects.

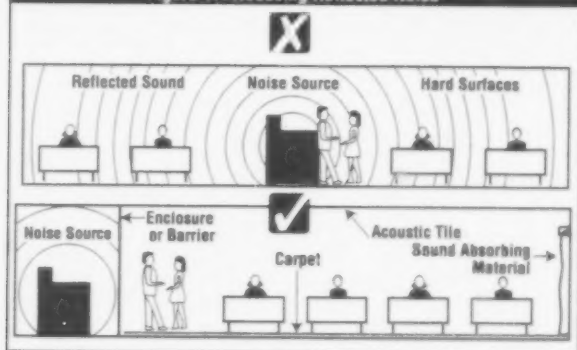
Sound absorbing materials on the walls, ceiling and floor reduce the reflected noise. The amount of reduction is 5 - 10 dB for high-pitched sounds and 2 - 3 dB for low pitched sounds. Such absorbing materials do not provide any protection against sound coming directly from the source to the listener. Therefore, the benefit is significant when persons are not close to the noise sources, and when noise sources are distributed over a wide area.

Sound Barriers and Deflectors

Wood or metal panels lined with acoustic material placed in front of or around a noisy machine may reduce the noise level reaching persons on the other side of the barrier. The amount of reduction depends on:

- The barrier material
- Location of barrier with respect to noise source
- Type of noise

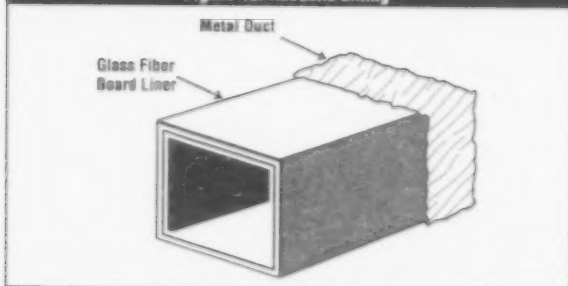
Figure 17: Reducing Reflected Noise



Acoustic Lining

Noise transmitted through ducts, pipes or electrical panels can be reduced by lining the inside surface of such passageways with sound absorbing materials. In typical duct installations, noise reduction for high pitched sounds is of the order of 2 – 3 dB per linear foot of 2.5 cm (1 inch) thick acoustic lining.

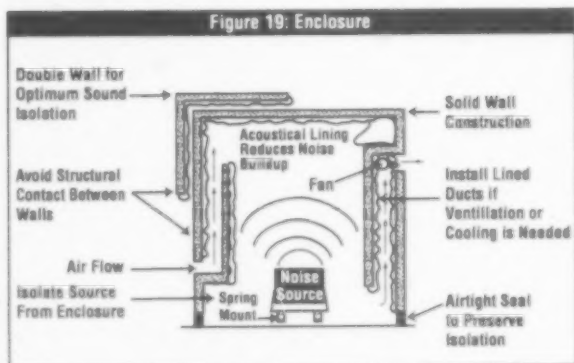
Figure 18: Acoustic Lining



Enclosures

Sometimes it is much more practical to enclose the noise source instead of altering the machine. Total enclosures should be used when a large noise reduction (15 dB or more) are required. The following factors must be considered an enclosure:

1. The walls of the enclosure must be reasonably thick.
2. The enclosure should be airtight to contain the sound.
3. Absorbent lining on the inner surface of the enclosure will reduce reverberant sound build up.
4. There should be no contact between enclosure and noise source.



Active Noise Cancellation

Active noise cancellation is an alternative noise reduction technique. The technique is based on the principle that two sounds of equal magnitude but opposite wave phase interfere and cause zones of extinction. This principle has been used to reduce noise levels in industry as well as in producing active ear protectors.

Active noise control is a highly sophisticated technology which must be designed and implemented by experts in the field.

4. Hearing Protection

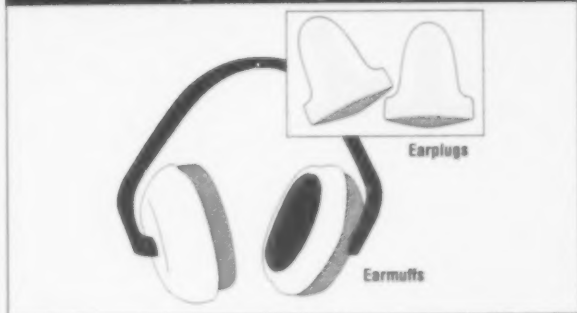
Selection of Hearing Protection

The choice of hearing protectors is a very personal one, and depends on a number of factors, including acoustics, comfort, and the suitability of the hearing protector for both the worker and the environment. Where protectors must be used, it is advisable to provide a choice of different types.

The human aspects of hearing protection are particularly important, since the only useful kind of protection is the protection that is actually worn. Some people do not accept particular kinds of protectors. Every human being is different, and the anatomy of the ear and ear canal can vary significantly from person to person.

The bottom line on hearing protection is worker preference. If the worker does not like the type of protection (for example, if it is uncomfortable or impractical), it will not be worn. However, there are many factors to consider when choosing adequate hearing protectors.

Figure 20: Hearing Protection



Advantages and Limitations of Earplugs and Earmuffs

Earplugs

Earplugs can be mass-produced or individually moulded to fit the ear, and they can be reusable or disposable. On the positive side, they are simple to use, less expensive than muffs, and more comfortable in hot or damp work areas. On the negative side, they are not as visible as muffs and a supervisor cannot readily check to see if workers are wearing them. They must be properly inserted to provide adequate protection.

Earmuffs

The type of earmuffs can vary with respect to the material and depth of the dome, the material filling the cuff, and the force of the headband. The deeper and heavier the dome, the greater the low-frequency attenuation provided by the protector. Fluid-filled cuffs, as opposed to foam-filled cuffs, provide more low-frequency attenuation and a better seal for workers wearing eyeglasses. The headband must fit tightly enough to maintain a proper seal, yet not be too tight for

comfort. On the positive side, earmuffs can usually provide greater protection than plugs, although this is not always true. They are easier to fit, generally more durable than plugs, and they have replaceable parts. On the negative side, they are more expensive, and often less comfortable than plugs, especially in hot work areas. In areas where noise levels are very high, muffs and plugs can be worn together to give better protection.

Table 19: Comparison of Hearing Protection

Earplugs	Earmuffs
Advantages • Small and easily carried. • Convenient to use with other personal protective equipment (can be worn with earmuffs). • More comfortable in hot, humid work areas. • Convenient for use in confined work areas.	Advantages • Less attenuation variability among users. • Designed so that one size fits most head sizes. • Easily seen at a distance to assist in the monitoring of their use. • Not easily misplaced or lost. • May be worn with minor ear infections.
Disadvantages • Require more time to fit. • Difficult to insert and remove. • May irritate the ear canal. • Easily misplaced. • More difficult to see and monitor usage. • Get dirty when your hands are dirty.	Disadvantages • Heavier, less portable • Inconvenient for use with other personal protective equipment. • Uncomfortable in hot, humid work areas. • Inconvenient for use in confined work areas. Seals may be broken by safety glass.

Standards

The Canadian Standard CSA Z94.2 entitled Hearing Protectors gives guidelines for the selection of hearing protectors to suit the level of noise in the workplace. In the USA, criteria for hearing protectors is outlined in the 29 CFR 1910.95(i)(1) of the Occupational Noise Exposure standard.

Noise Reduction Rating (NRR) of Hearing Protectors

The noise reduction rating is a single number description of the noise reduction capability of a hearing protector. NRR is used to determine effective exposure of a person wearing a hearing protector.

Table 20: Examples of NRR Values of Some Hearing Protectors

MAKE AND MODEL	NRR
3M, disposable ear plug 1100	29
Bilsom International, Inc., ear plug, Soft 5048	26
Earmuff Viking	29
Howard Light Industries, ear plug, LPF 1/30	30
Earmuff Quiet Talk QT800	29
Cabot Safety Corporation, E-A-R Taperfit 2	33
Earmuff 820-UC	24
Wilson Safety Products, ear plug, Sound Silencer EP 300	27
Earmuff, Sound Barrier 390 AL-H	24

Source: *The NIOSH Compendium of Hearing Protection Devices*, DHHS publication No. 95-105. National Institute of Occupational Safety and Health (NIOSH), Cincinnati, OH, USA (1995)

Detailed calculation of the protection provided by a hearing protector involves using octave band analysis of the workplace noise and the noise attenuation provided by the hearing protector for noise in each octave band.

The following short cut method is often used when only A-weighted sound level in dB(A) is measured.

Effective Exposure in dB(A) =

Measured Sound Level in dB(A) - (NRR - 7)

Under workplace conditions, hearing protectors are known to provide less protection compared to that expected using the above formula. NIOSH (National Institute of Occupational Safety and Health, USA (NIOSH) recommends that in absence of user fit data, the labelled NRR should be derated as follows:

Earmuffs

Subtract 25% from the manufacturer's labeled NRR

Formable earplugs

Subtract 50% from the manufacturer's labeled NRR

All other earplugs

Subtract 70% from the manufacturer's labeled NRR

To determine the effective noise reduction subtract 7 from the derated NRR

Example:

Given: Workplace Noise TWA = 98 dB(A)

Earplug with NRR = 29

Derated NRR = 50 % of 29 = 14.5

Effective protection = 14.7 - 7 = 7.5 dB(A)

Effective Noise Level = 98 - 7.5 = 90.5 dB(A)

Using Double Protection: Earmuff Plus Earplug

Double protection, using earplugs and earmuffs is generally recommended in areas with a very high noise level. The protection provided by this combination is about 5 dB higher than the better of the two protectors. OSHA recommends the following method for evaluating the effectiveness of the double protection:

Step 1: Calculate the field adjusted protection for the higher rated protector

Step 2: Add 5 dB to this field adjusted protection

Hearing Protection Must Be Worn All the Time

Ear protectors must be used ALL THE TIME to get the full benefit. Table 21 gives a maximum protection provided for non-continuous use of an ideally-fitted, infinitely-efficient hearing protector.

Table 21: Time Hearing Protection is Worn and the Maximum Protection Provided

PERCENT TIME USED (%)	MAXIMUM PROTECTION (dB)
50	3
60	4
70	5
80	7
90	10
95	13
99	20

Example: If the hearing protector is removed for 30 min. in an 8-hour shift, the maximum protection will be only 12 dB.

Tips for Hearing Protection Use

SELECT hearing protector that is:

- adequate for the job;
- capable of providing desired protection; and
- comfortable enough to be used all the time during work shift.

FOLLOW manufacturer's instruction for use, care and maintenance of the hearing protector.

MAKE SURE that your hands are clean before handling earplugs.

ENSURE proper fit.

- Earplugs must tightly seal the ear canal.
- Earmuffs must fit snugly against the side of the head.

DO NOT use radio headsets as a substitute for a hearing protectors

DO NOT modify hearing protectors.

Hearing Protectors and Ability to Understand Speech

In very low-level background noise, hearing protectors reduce the ability to understand speech. For moderate background noise (about 80 dB(A)), hearing protectors have almost no effect on the ability to understand speech for persons with normal hearing. For hearing-impaired persons, hearing protectors reduce the ability to understand speech for low-to-moderate levels of background noise. For high-level background levels, hearing protectors increase the speech hearing ability of persons with normal hearing. For hearing impaired persons, the effect of hearing protectors on the ability to understand speech is not clearly understood.

5. Hearing Measurement: Audiometric Test Program

Audiometry is an important part of the hearing conservation program. It is the only method of determining if hearing loss is being prevented. Although existing hearing loss cannot be cured, the data can be used to:

- identify persons for follow-up and counseling;
- determine general trends in the hearing status of workers;
- stop further increases in hearing loss by implementing noise control measures ;
- emphasize importance of noise control measures in employee training sessions;
- motivate employees to use hearing protection; and
- trigger changes in the hearing loss prevention program.

Tests are done by a qualified audiometric technician. It is essential that the worker has spent at least 14-hours without workplace noise before a baseline test is performed. For subsequent tests, there is no need of further precautions: if the worker is properly protected at his workplace, there will not be a temporary threshold shift (TTS). If there is TTS, then it will show on the audiogram and indicate the need for noise control action.

6. Administrative Controls

Having a hearing conservation program is the primary administrative control. Other administrative controls include:

- posting warning signs in noisy areas;
- reducing workers exposure time to noise;
- organizing tasks so that exposure time is shortened;
- notifying workers about their noise exposure; and
- organizing education and training sessions for workers and their supervisors.

Administrative Support

The responsibility for implementing noise-reduction strategies is shared by employees and management. The workers are greatly encouraged if management demonstrates a commitment to reduce workplace noise. The following examples of administrative actions which can be taken to reduce noise exposure:

- High noise level areas should be identified by posting labels.
- Hearing protectors should be made mandatory in noisy areas.
- Access to noisy areas should be limited to persons working in these areas.
- Employers should conduct periodic training of workers (especially new workers) to reinforce understanding of the risks of noise exposure, and the methods of reducing noise-induced hearing loss.

7. Employee Training

The only way to ensure that hearing protectors are worn is by raising employee awareness through training sessions. Several types of sessions can be used:

- Individual sessions: can be conducted on a one-to-one basis (e.g., during a hearing test). In such sessions, it is easy to provide personal attention and clarify all doubts.
- Training sessions: organized specifically for this purpose. A knowledgeable person leads the training session, presents the facts, and is able to answer questions.
- Safety meetings: organized to deal with specific workplace hazards. Unfortunately, in general they tend to be too short and not well presented.

The timetable for a typical training session (30-45 min.) will be as follows:

- Introduction (5 min.), where the speaker introduces himself and clearly states the objective of the session.
- A short video (no more than 10 min) is shown.
- The video is commented on (5 min) and questions are answered. Possible questions are:
 - Why to wear protectors?
 - When to wear them?
 - Where to wear them?
 - How to wear them?
 - How to take care of them?

The company policy on noise control is discussed, as well as the current legislation (5 min.)

8. Program Evaluation and Continuous Improvement

A hearing conservation program has to contain elements regarding its own maintenance and assessment of its performance. In essence, the person in charge of the program should be able to defend its very existence on the basis of the results obtained through the reduction of Workers' Compensation claims and/or hearing losses.

The assessment can be done by auditing each of the program's steps and seeing how well they are being executed. Essential questions would be: are all elements; in place. Are there periodic training; and awareness sessions? What are the results from the audiometric tests, etc.?

The program has to be reviewed periodically to see if there is a need for changes. Table 22 is an example of program checklist. This checklist should be used only as a guideline to develop workplace specific checklists.

**Table 22: Hearing Conservation Program
Evaluation Checklist**

PROGRAM ELEMENT	STATUS	RECOMMENDATION
Management commitment		
Policy established		
Responsibility defined		
Resources allocated		
Noise regulation awareness		
Responsibility assigned		
Current information maintained		
Hazard Recognition		
Noise monitoring done		
Noise maps available		
Employee exposure records:		
Available		
Posted		
Communicated to employees		
Noise controls		
Needs identified		
Options explored		
Responsibility assigned		
Supervisors consulted		
Hearing protection		
Program in place		
Ear protectors made available		
Employees trained in proper use		
Ear protectors regularly:		
Checked		
Maintained		
Replaced		

PROGRAM ELEMENT	STATUS	RECOMMENDATION
Supervisors wear ear protection		
Audiometry		
Policy defined		
Hearing tests made available		
Records kept confidential		
Follow-up actions taken		
Training		
Conducted periodically		
Instructor qualified		
Effectiveness evaluated		
Updated to meet needs		
Supervisors / managers involved		
Administrative controls		
Practices as defined in OHS law		
Noisy areas posted		
Compliance with policies enforced		
Purchasing policy to buy quieter machines		

Occupational Health and Safety Legislation

Canadian Occupational Health and Safety Legislation

1. What Does the OH&S Legislation Say?

Government's Responsibilities

Worker's Rights

Worker's Responsibilities

Supervisor's Responsibilities

Employer's Responsibilities

Joint Health and Safety Committee

Work Refusals

2. Workplace Hazardous Material Information System (WHMIS)

Hazard Symbols and Classes

3. Fire Code

4. Building Code

US Occupational Health and Safety Legislation

General Outline

Duties of Employer

Duties of Employee

Key Provisions

Hazard Communication

Hazard Warning Symbols

Canadian Occupational Health and Safety Legislation

The purpose of Occupational Health and Safety (OH&S) legislation is to protect employees against hazards on the job. It outlines the general rights and responsibilities of the employer, the supervisor and the employee.

The law makes both you and your employer responsible for workplace health and safety.

1. What does the OH&S legislation say?

Each of the provinces and the federal government have their own OH&S legislation. The details of the OH&S legislation vary slightly from one jurisdiction to another, but the basic elements are the same. These basic elements include the following:

Government's Responsibilities

- i) to develop and enforce occupational health and safety legislation
- ii) to conduct workplace inspections
- iii) to disseminate information
- iv) to promote training, education and research

Worker's Rights

- i) to refuse unsafe work
- ii) to participate in the workplace health and safety activities through Joint Health and Safety Committee (JHSC) or worker health and safety representative
- iii) to know actual and potential dangers in the workplace

Worker's Responsibilities

- i) to work in compliance with OH&S act and regulations and company policy
- ii) to use personal protective equipment and clothing as directed by the employer

-
- iii) to report workplace hazards and dangers
 - iv) to participate in OH&S training

Supervisor's Responsibilities

- i) to advise workers of potential and actual hazards
- ii) to take every reasonable precaution in the circumstances for the protection of workers
- iii) to ensure that workers use prescribed protective equipment devices

Employer's Responsibilities

- i) to take every reasonable precaution to ensure workplace is safe
- ii) to establish and maintain a joint health and safety committee, or cause workers to select at least one health and safety representative
- iii) to consult with and cooperate with the joint health and safety committee or worker health and safety representative
- iv) to train employees about any potential hazards
- v) to supply personal protective equipment and ensure workers know how to use the equipment safely and properly
- vi) to immediately report all critical injuries to the government department responsible for OH&S
- vii) to train all employees on how to safely use, handle, store and dispose of hazardous substances and handle emergencies

Joint Health and Safety Committee

- i) must be composed of one half management and at least one half labour representatives
- ii) must meet regularly according to time intervals specified in the health and safety legislation.
- iii) must be co-chaired by one management chairperson and one worker chairperson
- iv) employee representatives are elected or selected by the workers or their union

Role of Joint Health and Safety Committee

- i) to act as an advisory body
- ii) to identify hazards and obtain information
- iii) to recommend corrective actions
- iv) to assist in resolving work refusal cases
- v) to participate in accident investigations and workplace inspections

Work Refusals

You can refuse work if you have reason to believe that the situation is unsafe to either yourself or your co-workers.

- i) You must report to your supervisor that you are refusing to work and state why you believe the situation is unsafe.
- ii) You, your supervisor, and a JHSC member or worker representative will investigate.
- iii) You return to work if the problem is resolved.
- iv) If the problem is not resolved, a government health and safety inspector is called.
- v) Your supervisor may assign you reasonable alternative work.
- vi) Inspector investigates and gives decision.
- vii) You are protected from discipline or any other reprisal from your right to refuse unsafe work.

2. Workplace Hazardous Materials Information System - WHMIS (Pronounced whimiss)

WHMIS applies to all Canadian workplaces. It requires that all workers who work with or near a hazardous substance (controlled product) be informed about its potential hazards and recommended safe work practices.

WHMIS requires that information be provided in three ways:

1. All controlled products used in the workplace must have a WHMIS label on the container.
2. Material Safety Data Sheets (MSDS) and hazard information must be readily available in the workplace. An MSDS summarizes the health and safety information about the product.
3. Workers must receive training to be able to recognize and work safely with chemicals. The employer must consult the joint health and safety committee to select a suitable training program.

The HAZARD SYMBOL is an important part of the WHMIS label. It warns the user that a particular hazard exists.

Actual hazards from toxic substances depend on the amount (level and duration) of exposure. A brief exposure at high levels may result in chemical poisoning within hours. Prolonged exposure at low levels may cause illness after several years.

Hazard Symbols and Classes



Class A
Compressed Gas

Contents under high pressure. Cylinder may explode or burst when heated, dropped or damaged.



Class B
Combustible and
Flammable Material

May catch on fire when exposed to heat, spark or flame. May burst into flames.



Class C
Oxidizing Material

May cause fire or explosion when in contact with wood, fuels and other combustible material.



Class D, Division 1
Poisonous and
Infectious Material:
immediate and
serious toxic effects

Poisonous substance. A single exposure may be fatal or cause serious or permanent damage to health.



Class D, Division 2
Poisonous and
Infectious Material:
other toxic effects

Poisonous substance. May cause irritation. Repeated exposure may cause cancer, birth defects, or other permanent damage.



Class D, Division 3
Poisonous and
Infectious Material:
biohazardous
infectious material

May cause disease or serious illness. Drastic exposures may result in death.



Class E
Corrosive Material

Can cause burns to eyes, skin or respiratory system.



Class F
Dangerously
Reactive Material

May react violently causing explosion, fire or release of toxic gases, when exposed to light, heat, vibration or extreme temperatures.

3. Fire Code

The fire code sets the requirements for fire prevention and protection. These include requirements for:

- i) building design complementing the building code
- ii) fire protection and fire detection systems
- iii) storage of specific materials
- iv) fire inspections

Authority

The Fire Code is enforced by the local fire department in your city.

Information and Training

Contact your local fire department for additional information and employee education in fire safety procedures.

4. Building Code

The building code sets standards and guidelines for buildings, structures and systems. Heating, ventilation, storage, renovations, and maintenance requirements are part of the Building Code.

The objective of the Building Code is to make sure that:

- i) buildings are structurally adequate for their planned use
- ii) structures and materials can withstand temperature extremes and ice and snow loads
- iii) building design meets fire safety code, electrical safety code and other regulatory requirements
- iv) building is suitable for the planned occupancy

Information

Contact your employer or the city for information regarding the building code applicable to your workplace.

U.S. Occupational Health and Safety Legislation

General Outline

In the United States of America (USA) the Occupational Safety and Health Act is popularly known as OSHA Act. The Occupational Safety and Health Administration (OSHA) is responsible for administering the OSHA Act.

The OSHA ACT does not cover the following four categories of people:

- self-employed persons
- farms which employ only immediate family members of the farm employer
- workers covered by other legislation
- state and local government employees

Regulations dealing with OSHA are published in Title 29 of the Code of Federal Regulations as:

29 CFR Part 1910 Occupational Safety and Health Standards

29 CFR Part 1926 Construction Standards

These standards define exposure limits, exposure monitoring methods, medical surveillance and protective measures.

Duties of Employer

The OSHA Act sets out two main duties for employers:

- Employers must provide a workplace which is free from hazards that are known to cause or likely to cause death or serious physical harm to employees.
- Employers must comply with occupational safety and health standards under the Act.

Duties of Employee

Employees must comply with occupational safety and health standards, rules, regulations and orders which are applicable to their own conduct and actions.

Key Provisions

Some Key Provisions of the OSHA Act

- to assure, insofar as possible, that every employee has safe and healthy working conditions
- to require employers to maintain accurate records of exposures to potentially toxic materials or harmful physical agents and inform employees of the monitoring results
- to allow at least one employee representative to be present during the walkaround inspection
- to encourage free and open exchange of information between employees and the inspector
- to implement procedures for investigating alleged violations, at the request of any employee or employee representatives, issuing citations and assessing monetary penalties against employers

Hazard Communication

The intent of the OSHA Hazard Communication Standard is to provide employees with information and training about the potential health hazards from exposure to workplace chemicals. The Standard requires that employee training include:

- explanations of the requirements of the standard
- identification of workplace operations where hazardous chemicals are present
- knowledge of the methods and observations used to detect the presence of hazardous workplace chemicals
- assessment of the physical and health hazards of those chemicals

-
- warnings about hazards associated with chemicals in unlabelled pipes
 - descriptions of hazards associated with non-routine tasks
 - details about the measures employees can take to protect themselves against these hazards, including specific procedures
 - explanation of the labeling system
 - instructions on location and use of material safety data sheets (MSDSs)
 - details on the availability and location of the hazardous materials inventory, MSDSs, and other written hazard communication material

Hazard Warning Symbols

Chemicals produced in the USA come under OSHA Hazard Communication Standard. The label on the container must warn about potential hazards of the product. OSHA does not require hazard symbols on the label, however, the skull and crossbones symbol is acceptable on containers of highly toxic substances, and the flame symbol is acceptable on containers of flammable substances.

Section IX

Information Sources

In Canada

1. Canadian Centre for Occupational Health and Safety (CCOHS)
2. Responsibility for Occupational Health and Safety

In the USA

1. US Federal Safety and Health Agencies
 - EPA
 - NIOSH
 - OSHA
 - OSHA Regional Offices

In Canada

1. Canadian Centre for Occupational Health and Safety (CCOHS)

Customer Service

Phone (905) 570-8094

Toll-free 1-800-668-4284 (Canada and US only)

Fax (905) 572-2206

E-mail custserv@ccohs.ca

Web Site: www.ccohs.ca

Inquiries

Phone (905) 572-4400

Toll-free 1-800-263-8466

Fax (905) 572-4500

E-mail inquiries@ccohs.ca

OSH Answers Web Site: www.ccohs.ca/oshanswers

2. Canadian Governmental Departments with Chief Responsibility for Occupational Health and Safety

Federal Jurisdiction

Human Resources Development Canada

Labour Branch (819) 953-0155

Workplace Information Directorate

1-800-567-6866

Labour-Management Partnerships Program

1-800-563-5677

Web Site: labour-travail.hrdc-drhc.gc.ca/eng/

Alberta

Alberta Labour Workplace Health and Safety

General Inquiries (403) 427-8842

Fax (403) 427-5698

Web Site: www.gov.ab.ca/lab/

British Columbia

Workers' Compensation Board of British Columbia

General Inquiries (604) 273-2266

Toll free in B.C. 1-800-661-2112

Fax (604) 279-3151

Web Site: www.wcb.bc.ca

Manitoba

Department of Labour Workplace Safety and Health Division

General Inquiries (204) 945-3602

Toll free in Manitoba 1-800-282-8069

Fax (204) 945-4556

WHMIS (204) 945-3603

Web Site: www.gov.mb.ca/labour/safety/index.html

New Brunswick

Workplace Health, Safety and Compensation Commission of New Brunswick

General Inquiries (506) 632-2200

Toll free in N.B. 1-800-442-9776

Fax (506) 738-4227

Web Site: www.whscc/nb.ca/

Newfoundland

Workplace Health and Safety Compensation Commission

General Inquiries (709) 778-1000

Toll-free in Newfoundland 1-800-563-9000

Web Site: www.whscc.nf.ca

Northwest Territories

Department of Public Works and Services

General Inquiries (403) 873-7468

Fax (403) 873-0117

Web Site: www.gov.nt.ca

Nova Scotia

Department of Labour Occupational Health and Safety Division

General Inquiries (902) 424-4125

Fax: (902) 424-3239

Toll free in Nova Scotia 1-800-952-2687

Web Site: www.gov.ns.ca/labro/ohs/index2.htm

E-mail: labrohs@gov.ns.ca

Ontario

Ministry of Labour Occupational Health and Safety Branch

General Inquiries (416) 326-7770

Toll free in Ontario 1-800-268-8013

Fax: (416) 326-7761

Web Site: www.gov.on.ca/LAB/main.htm

E-mail: weblab@gov.on.ca

Prince Edward Island

Workers' Compensation Board

14 Wexmouth Street

P.O. Box 757

Charlottetown C1A 7L7

General Inquiries: (902) 368-5680

Fax: (902) 368-5705

Web Site: www.wcb.pe.ca/index.html

Québec

CSST (Commission de la santé et de la sécurité du travail du Québec)

General Inquiries (514) 873-7183

Fax (514) 873-7007

Service répertoire toxicologique

Phone (514) 873-6374

Internet <http://www.csst.qc.ca>

Saskatchewan

Department of Labour Occupational Health and Safety Branch

General Inquiries (306) 787-4496

Toll free in Saskatchewan 1-800-567-7233

Web Site: www.labour.gov.ska/

Yukon

Workers' Compensation, Health and Safety Board

General Inquiries (403) 667-5645

Fax (403) 393-6279

Toll free in the Yukon 1-800-661-0443

Web Site: www.wcb.yk.ca

In the USA

1. US Federal Safety and Health Agencies

EPA

401 M ST., SW
Washington, DC 20460-0003
Phone: (202) 260-2090
Web Site: www.epa.gov/

NIOSH

National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226

Publications Dissemination

General Inquiries (513) 533-8328
Fax (573) 533-8573
Hazards Evaluations and Technical
Assistance Branch (513) 841-4382
Toll-free in the US 1-800-356-4674
Web Site: www.cdc.gov/NIOSH/homepage.html

OSHA

Occupational Safety & Health Administration

200 Constitution Ave., NW
Washington, DC 20210
Phone (202) 693-1999
Toll free: 1-800-321-OSHA
Web Site: www.osha-slc.gov

OSHA Training Institute

1555 Time Dr.
Des Plaines, IL 60018
Phone (708) 297-4810

OSHA Regional Offices

Region I: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont US Dept. of Labor—OSHA

JFK Federal Building, Room E340
Boston, MA 02203 (617) 565-9860
Fax (617) 565-9827
Web Site: www.osha.gov/oshdir/r01.html

Region II: New Jersey, New York, and Puerto Rico USA Dept. of Labor—OSHA

201 Varick St., Rm. 670
New York, NY 10014
Phone (212) 337-2378
Fax (212) 337-2371
Web Site: www.osha.gov/oshdir/r02.html

Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia and West Virginia USA Dept. of Labor—OSHA

Gateway Bldg.
3535 Market St. Suite 2100
Philadelphia, PA 19104
Phone (215) 596-1201
Fax (215) 596-4872
Web Site: www.osha.gov/oshdir/r03.html

Region IV: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee

USA Dept. of Labor—OSHA
1375 Peachtree St., NE Suite 587
Atlanta, GA 30367
Phone (404) 562-2300
Fax (404) 562-2295
Web Site: www.osha.gov/oshdir/r04.html

**Region V: Indiana, Illinois, Michigan, Minnesota,
Ohio, and Wisconsin USA Dept. of Labor—OSHA**

230 S. Dearborn St., Rm. 3244

Chicago, IL 60604

Phone (312) 353-2220

Fax (312) 353-7774

Web Site: www.osha.gov/oshdir/r05.html

**Region VI: Arkansas, Louisiana, New Mexico,
Oklahoma, and Texas USA Dept. of Labor—OSHA**

525 Griffin St., Rm. 602

Dallas, TX 75202

Phone (214) 767-4731

Fax (214) 767-4137

Web Site: www.osha.gov/oshdir/r06.html

**Region VII: Iowa, Kansas, Missouri, and Nebraska
USA Dept. of Labor—OSHA**

City Center Square

1100 Main St., Suite 800

Kansas City, MO 64105

Phone (816) 426-5861

Fax (816) 426-2750

Web Site: www.osha.gov/oshdir/r07.html

**Region VIII: Colorado, Montana, North Dakota,
South Dakota, Utah, and Wyoming USA Dept. of
Labor—OSHA**

1999 Broadway, Suite 1690

Denver, CO 80202-5716

General Inquiries

Phone (303) 844-1600

Fax (303) 844-1616

Web Site: www.osha.gov/oshdir/r08.html

**Region IX: American Samoa, Arizona, California,
Guam, Hawaii, Nevada, and Trust Territory of the
Pacific Islands**

USA Dept. of Labor—OSHA

71 Stevenson St., 4th Floor

Suite 420

San Francisco, CA 94105

Phone (415) 744-6670

Fax (415) 744-9990

Web Site: www.osha.gov/oshdir/r09.html

Region X: Alaska, Idaho, Oregon, and Washington

USA Dept. of Labor—OSHA

1111 Third Ave.

Suite 715

Seattle, WA 98101-3212

Phone (206) 553-5930

Fax (360) 553-6499

Web Site: www.osha.gov/oshdir/r10.html

Appendix

Appendix A

Sound Pressure Level Calculations

1. Definition of Decibel (dB)
2. Convert Dose to Equivalent Sound Level (Leq)

Appendix B

Relevant Noise Standards

1. Canadian Standards Association
2. American National Standards Institute (ANSI)

Appendix C

Further Reading

Appendix D

Sound Absorbing and Sound Attenuation Characteristics of Some Building Materials and Furnishings

Appendix A

Sound Pressure Level Calculations

1. Definition of Decibel (dB)

Sound Pressure Level (dB)

$\approx 20 \log (\text{Sound Pressure/Reference Pressure})$

Reference sound pressure is 0.00002 pascals or 20 micropascals

The "log" or logarithm of a number is the power to which the number 10 must be raised to

produce that number. For example:

$\log 10 = 1$ because $10^1 = 10$

$\log 100 = 2$ because $10^2 = 100$

$\log 1000 = 3$ because $10^3 = 1000$

$\log 10000 = 4$ because $10^4 = 10000$

The above examples are simple and straightforward ones. We do not always deal with multiple of 10s.

However, we can find the log for any given number using:

- log tables found in almost all mathematics books, or
- a calculator.

For example:

$\log 2 = 0.3$ because $10^{0.3} = 2$

$\log 5 = 0.7$ because $10^{0.7} = 5$

$\log 7 = 0.85$ because $10^{0.85} = 7$

$\log 257 = 2.4$ because $10^{2.4} = 257$

The use of logarithms allows us to compress a large range of numbers into a shorter manageable range. For example, the log scale for numbers in the 10-10,000 range is compressed into the 1-4 range.

Zero decibel (0 dB) corresponds to a reference sound pressure of 20 micropascal (0.00002 Pa) which is the weakest sound that a healthy young person can barely hear.

Reference Sound Pressure Level

$$= 20 \log (0.00002 / 0.00002) = 20 \log (1) = 0 \text{ dB}$$

In a quiet room, the sound pressure is 0.002 Pa. The corresponding sound pressure level will be:

$$\begin{aligned} 20 \log (0.002 / 0.00002) &= 20 \log (100) \\ &= 20 \times 2 = 40 \text{ dB} \end{aligned}$$

A typical gasoline-powered lawn mower produces sound pressure of 1 Pa. Corresponding sound pressure level will be:

$$\begin{aligned} 20 \log (1 / 0.00002) &= 20 \log (50\,000) \\ &= 20 \times 4.7 = 94 \text{ dB} \end{aligned}$$

2. Convert Dose to Equivalent Sound Level (Leq):

$$Leq = 10 \log (D/100) + 10 \log (8/T) + Lc$$

where

D = Percent dose

T = the duration of the measurement in hours

Lc = Noise Exposure Limit for 8-hours

Example: Use the following data to determine Leq for 8-hour work shift:

Dosimeter setting:

Criterion level 90 dB(A)

Threshold level 80 dB(A)

Exchange rate 3 dB

Duration of sampling: 4 hours

Dosimeter reading: 110%

Given $D = 110\%$ for 4 h and $L_c = 90$ dBA,

$$\begin{aligned} L_{eq} &= 10 \log(110/100) + 10 \log(8/4) + 90 \\ &= 10 \log 1.1 + 10 \log 2 + 90 \\ &= 10 \times 0.04 + 10 \times 0.3 + 90 \\ &= 93.4 \text{ dB(A)} \end{aligned}$$

If the dosimeter is set for a 5 dB exchange rate the following formula should be used to convert dose to time weighted average (TWA) sound pressure level:

$$\begin{aligned} L(\text{TWA}) \\ &= 16.61 \log(D/100) + 16.61 \log(8/T) \text{ dB(A)} + L_c \end{aligned}$$

Appendix B

Relevant Noise Standards

1. Canadian Standards Association

CSA Z94.2

Hearing Protectors

CSA Z107.31

Test Procedures for the Measurement of Sound Levels from Agricultural Machines.

CSA Z107.32

Test Procedure for the Measurement of Sound Emitted from Construction,

Forestry, and Mining Machines to the Operator Station and Exterior of the Machine.

CSA Z107.51

Procedure for In-Situ Measurement of Noise from Industrial Equipment.

CSA Z107.52

Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources.

CSA Z107.53

Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities.

CSA Z107.54

Procedure for Measurement of Sound and Vibration Due to Blasting Operations.

CSA Z107.56,

Procedures for the Measurement of Occupational Noise Exposure, 1994.

CSA Z107.4-M86

Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening.

2. American National Standards Institute (ANSI)

ANSI S3.44 - 1996

Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment, 1996.

ANSI S12.7-1986 (R1998)

Methods for Measurement of Impulse Noise .

ANSI S12.13

Standard for the Evaluation of Hearing Conservation Program Effectiveness.

ANSI S12.19-1996

Measurement of Occupational Noise Exposure .

ANSI S12.16-1992 (R1997)

Guidelines for the Specification of Noise of New Machinery.

ANSI S1.25-1991 (R1997)

Specification for Personal Noise Dosimeters.

International Organization for Standardization

ISO 7960:1995

Airborne Noise Emitted by Machine Tools - Operating Conditions for Woodworking Machines.

ISO 7182:1984

Acoustics - Measurement at the Operators Position of Airborne Noise Emitted by Chainsaws.

ISO 5128:1980

Acoustics – Measurement of Noise Inside Motor Vehicles.

ISO 11094:1991

Acoustics – Test Code for the Measurement of Airborne Noise Emitted by Power Lawn Mowers, Lawn Tractors, Lawn and Garden Tractors, Professional Mowers, and Lawn and Garden Tractors with Mowing Attachments.

Appendix C

FURTHER READING

International Organization for Standardization (ISO),
Acoustics-Determination of Occupational Noise
Exposure and Estimation of Noise-Induced Hearing
Impairment, Standard ISO 1999-1990, 1990.

National Institute for Occupational Safety and Health
(NIOSH). Criteria for a Recommended Standard
Occupational Noise Exposure, Revised DHHS (NIOSH)
Pub. No 98-126, 1998.

National Institute for Occupational Safety and Health
(NIOSH). Preventing Occupational Hearing Loss: A
Practical Guide, DHHS (NIOSH) Pub. No. 96-110, 1996.

National Institute for Occupational Safety and Health
(NIOSH). Proposed National Strategy for the Prevention
of Work-Related, Noise-Induced Hearing Loss, Draft,
1986.

B. P. Pathak, K. Marha, and W. J. Louch, Industrial
Noise Levels Data Base, *Annals of Occupational
Hygiene*, Vol. 33 (1989) p. 269 - 274

Sataloff, R..T. and J.T. Sataloff. 1987. *Occupational
Hearing Loss*. New York: Marcel Dekker.

Appendix D

Sound Absorbing and Sound Attenuation Characteristics of Some Materials

Sound Absorption Coefficients of General Building Materials and Furnishings						
MATERIALS	COEFFICIENTS (Hz)					
	125	250	500	1000	2000	4000
Brick, unglazed	.03	.03	.03	.04	.05	.07
Brick, unglazed, painted	.01	.01	.02	.02	.02	.03
Carpet, heavy, on concrete	.02	.08	.08	.06	.24	.27
Same, on 40-oz hairfelt or foam rubber	.08	.24	.57	.69	.71	.73
Same, with impermeable latex backing on 40-oz hairfelt or foam rubber	.08	.27	.39	.34	.48	.63
Concrete Block, light, porous	.36	.44	.31	.29	.39	.25
Concrete Block, dense, painted	.10	.05	.06	.07	.09	.08
Fabrics:						
Light Velour, 10-oz per sq yd, hung straight, in contact with wall	.03	.04	.11	.17	.24	.35
Medium Velour, 14-oz per sq yd, draped to half area	.07	.31	.49	.75	.70	.60
Heavy Velour, 18-oz per sq yd, draped to half area	.14	.35	.55	.72	.70	.65
Floors:						
Concrete or terrazzo	.01	.01	.015	.02	.02	.02

MATERIALS	COEFFICIENTS (Hz)					
	125	250	500	1000	2000	4000
Linoleum, asphalt, rubber, or cork tile on concrete	.02	.03	.03	.03	.03	.02
Wood	.15	.11	.10	.07	.06	.07
Wood parquet in asphalt on concrete	.04	.04	.07	.06	.06	.07
Glass:						
Large panes of heavy plate glass	.18	.06	.04	.03	.02	.02
Ordinary window glass	.35	.25	.18	.12	.07	.04
Gypsum Board, Ω -inch, nailed to 2 x 4's 16" o.c.	.29	.10	.05	.04	.07	.09
Marble or Glazed Tile	.01	.01	.01	.01	.02	.02
Plaster, gypsum, or lime, smooth finish on tile or brick	.013	.015	.02	.03	.04	.05
Plaster, gypsum, or lime, rough finish on lath	.14	.10	.06	.05	.04	.03
Same with smooth finish	.14	.10	.06	.04	.04	.03
Plywood Paneling, 3/8-inch thick	.28	.22	.17	.09	.10	.11
Water Surface, as in a swimming pool	.008	.008	.013	.015	.020	.025
Air, Sabins per 1000 cubic feet	.06	.20	.16	1.20	2.60	7.40
Open Doors and Windows	1.00	1.00	1.00	1.00	1.00	1.00

Source: NIOSH Compendium of Materials for Noise Control published by U.S. Department of Health, Education, and Welfare. Tables of coefficients for various materials are available in many books on acoustics and architecture.

**Transmission Loss (dB) of Some Common Materials
Used for Acoustical Enclosures and Isolation Barriers**

MATERIALS	FREQUENCY (dB)						
	125	250	500	1000	2000	4000	8000
1/32 in. Thick Lead	22	24	29	33	40	43	49
3/4 in. Plywood	24	22	27	28	25	27	35
Lead vinyl (1 lb/ft ²)	15	17	21	28	33	37	43
16 gauge Steel	21	30	34	37	40	47	52
Sheet metal (viscoelastic laminate core)	15	25	28	32	39	42	47
1 in. Thick Plexiglass	25	28	32	32	34	46	46
Glass							
1/8 in. thick	11	17	23	25	26	27	28
1/4 in. thick	17	23	25	27	28	29	30
Concrete, 4 in. thick	29	35	37	43	44	50	55
Concrete block, 6 in.	33	34	35	38	46	52	55

Source: Lewis H. Bell; Industrial Noise Control: Fundamentals and Applications, New York: Marcel Dekker Inc. 1982



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